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THE INSURRECTION IN CUBA—SUGAR MANUFACTORY AT MANZANILLO, PILLAGED AND BURNT BY THE INSURGENTS.

THE INSURRECTION IN CUBA—THE RAILROAD BRIDGE OF THE CANEY LINE DESTROYED BY THE INSURGENTS.

THE INSURRECTION IN CUBA.

The struggle between Spain and the disaffected in Cuba has not the character of an ordinary war. There are neither armies nor pitched battles. As in all the revolutions in Central and South America it is a hand-to-hand conflict and depends largely upon the resources of the country and its natural advantages. Ambuscades, marches and counter-marches, which are prolonged almost indefinitely and in which numerous small bands of insurgents called partidas, commanded by leaders called cabecillas, ravage the country, are sufficient to hold in check a whole corps of an army. These bands, composed of a hundred, often several hundred, men, are made up in large part of negroes or mulattoes, equipped with arms of all kinds and wearing the large hats of the planters, operate principally in the eastern part of the island, in the provinces of Puerto Principe and Santiago de Cuba, where the heavily wooded and mountainous character of the country is specially adapted to the maneuvers and surprises of the guerillas. Arms and horses are taken from the inhabitants. Fierce and insatiable, they utilize the least accident of ground, and skirmishing without relaxation, thus they torment the Spanish troops, cutting telegraph wires and destroying railroads. They also destroy the storehouses, the coffee and tobacco plantations and the sugar works, which are situated in the center of the plantations. Sugar and tobacco constitute the principal industries in the greater Antilles. One of our engravings represents one of the three establishments at Manzanillo.

The insurgents take advantage of all manner of positions, trees even, especially palm trees, become points of attack, and one of our engravings shows insurgent troops firing on Spanish troops from palm trees.

A partida had attacked the village of Cristo, three leagues from Santiago de Cubaon May 6, and dislodged the Spaniards after a fusillade of two hours. The next day three hundred troops of the ninth Peninsular regiment reoccupied the village and on May 8 they made a new attack on the insurgents, who were forced from the village of Caney; the insurgents then destroyed the railroad bridge and part of the railway so that when the train bearing reinforcements of Spanish troops arrived, it was precipitated into a ravine. These troops were massacred after a terrible conflict on the banks of the stream and even in the water.—L'Illustration.

In a recent number of El Quixote, a Spanish paper published in Madrid, the distinguished Spanish statesman and patriot Senor F. Pi y Margall presents his views on the Cuban movement in very eloquent words.

Senor Margall was one of the presidents of the Spanish republic before Martinez Campos placed Alfonso XII on the throne, thereby again re-establishing a monarchical form of government. He is respected for his honesty and love of justice, and is very influential in the politics of Spain.

The following is a translation:

"We should work to re-establish the principles of justice. No nation has the right to occupy territories populated by other people unless with their consent. If a nation occupies them by force, those conquered can at any time fight them until they drive them from their soil.

"There is no possible limitation. Nothing can limit the right to freedom and independence. Whenever this principle was applied to our life, did we Spaniards understand so? For two centuries we fought against old Rome for our independence. During seven centuries we fought against the Arabs, who in three years had extended from Tarifa to Pirends. The limitation of centuries made no difference. Those of Seville and Granada were as Spanish as ourselves when we drove them away from the territory, as they were Spanish descendants for more than ten generations.

"We did not put down our arms until we drove them from our shores. In Malaga we carried our cruelty to the extreme of taking from them the gold and jewels that might have helped them in their exile. If we acted in that way, is it just that we call bandits those who are now fighting against us for their independence? For the same deeds and for the same cause must we call those bandits who here we call "heroes"? Heroes are called, all over America and over the world, those who in the first third of the century drove us away from Mexico, Guatemala, Colombia, Ecuador, Chile and Peru.

"Let us be just to those who are now fighting in Cuba. We should have given them long ago the autonomy to which they have an undisputable right. We should have united them to the metropolis by the ties of common interests only, national and international. We would have thus prevented not only the present war, but also that of 1868. How much blood and how much treasure we should have saved by this conduct!

"It was advised by reason, right, our own interests and the consideration of the vast colonial empire we had lost. Unfortunately for countries, more so than for individuals, the force of habit is irresistible. Nothing could persuade us to give up our old policy—a policy so little authorized by our own as well as other people's experiences.

"If there is now war in Cuba, it is all our fault. It is our duty to mend our error and stop it. The war of 1868 lasted ten years, and we could only stop it by a treaty. We then allowed the Cubans the rights and liberties enjoyed by Puerto Rico—the treaty by which we will have to end the present war if we are not beaten by Cuba. Let us make it now, when we are the stronger, and when our generosity cannot be construed as weakness. Seventeen years ago we gave them liberty. Let us now give them autonomy. Let us make them now the owners and arbiters of their destinies. Let us allow them to govern themselves politically and economically; and in order that they may be grateful for our generosity, let us help them to their autonomy without any disturbances or bloodshed.

"The feeling of patriotism is invoked against this conduct. Above the feeling of patriotism stands that of humanity, and, above all, the feeling of justice. Cuba is the graveyard of our young men. In these deplorable wars our soldiers die there by the thousands; some on account of the climate and others by the lead and steel of the enemy. The greater part of them go there by force and fight for a cause with which they are not in sympathy.

"Is it even human not to try to find the means of saving the lives of these men? It is irritating to read and hear one day and another that it is necessary to send to Cuba regiments and recruits in order to finish with the rebels and uphold and establish the national sovereignty. In order that their patriotism might not be considered as false, those who think that way should be the first to go with their sons in the advance guard of the army.

"It is easy to stay at home and send others to die, and it is easy, too, not to know anything about the war but by reading descriptions of the battles by our firesides in winter and under the shade of the trees in summer. The national sovereignty! Is it that the nation in order to be sovereign must absorb the life of the groups that make it up? Is it that sovereignty must carry along with it the slavery of the colonies? Its sovereignty limited to the national interests, it must be circumscribed to the life of relations to the colonists.

"National pride is also invoked to continue the war, as if it were dishonorable to a nation to grant what is just. Would the honor of the nation suffer less by continuing the war and losing in the end? Was it more honorable for us to have to ratify in Mexico, by the peace of Cordodo, the plan of Iguala, and to sign in Peru the shameful capitulation of Ayacucho?

"The war will increase our already desperate economic situation. It is only three months since the war was begun, and already it has cost \$7,000,000 in the last budget made up before the war. We had already a deficit of \$6,000,000, and you all know how these deficits are increased upon the final liquidation of the accounts. You can therefore calculate what our deficit will be at the termination of the new financial year if the war continues. F. Pi y Margall."

INFLUENCE OF SCIENCE ON MOUNTAINEERING.*

By Clinton T. Dent, Esq., F.R.C.S., M.R.I.

Between mountaineering in general and climbing, which is but a special branch of mountaineering, I desire for the purpose of this discourse to draw a clear distinction, but do not wish it to be supposed that my dwelling chiefly on mountaineering implies any depreciation of simple climbing. On the latter it is well nigh impossible to break new ground, save in the geographical sense. The climbers of mountains cannot justly be accused of any exaggerated tendency to reticence as regards their adventures. The technique of climbing is really simple, and considered as a craft, the subject has been fully dealt with. Indeed, the general principles that the climber has to bear in mind have been reduced to rules so few and so simple that many can quote, and a certain proportion can follow them.

I desire chiefly to-night to dwell for a short time on the part that science has played in developing the growth of mountaineering. This has not been adequately recognized. The popularity of mountaineering during the last thirty-five years, the period of greatest activity, has been too much laid to the credit of writers who have regarded and described the Alps as a field for the best of recreations. The more solid work was less before the world. Geologists and botanists, from the first, found in the Alps a magnificent field for pursuing their own branches of work; but in the matter of physical science the work done was speculative, not experimental. Men sought for evidence for or against the deluge, or elaborated vast hypotheses of the earth's formation. They concerned themselves little with attempts to explain the phenomena going on under their eyes, and there was little original investigation. In old books on the Alps, statements, often of the wildest nature, are found copied from one to another without the slightest trace of acknowledgment. Men whose lines of thought led them into the direction of physical research came late into the field, but gradually their work attracted in some quarters the attention due to a new departure. So there arose men who gathered from the amassed knowledge of works of science such facts and observations as might be turned to practical account in mountain exploration. Thus was developed the scientific mountaineer, who, on the mountains, could use his head as well as his limbs. He might or might not be one who made science his prime object when among the mountains. I am far from saying that this is the ordinary type of the mountaineer of to-day; but it must be the type of the mountaineer of the future who wishes to extend his sphere of exploration beyond the restricted field of the mid-European Alps. The pioneers were numerous. Such names as Agassiz, Studer, Rendu, Forbes, Ball, occur at once to the mind; but I must limit myself to-night to two only, De Saussure, during the last century, and Tyndall in recent times.

The true value of De Saussure's work can only be estimated by considering the scientific chaos with regard to glacial phenomena that was widely prevalent before and during his time. It is not long since that avalanches, mountain falls, the bursting of glacial lakes and such like occurrences were considered generally to be the work of fiends or evil spirits. The legends that smiling Alps were converted into snowfalls and glaciers as punishment for man's wickedness were widely credited. Dragons were supposed to haunt the mountains, and were implicitly believed in by men such as Wagner, the naturalist, little more than two hundred years ago. Long after the legendary ages, of which traces enough can still be found in the Alps, and still more plainly in other mountainous countries, the state of physical science as regards mountains and glaciers was in a very primitive condition, owing largely to the terror with which mountains were generally regarded. De Saussure reduced to order by direct observation, by experiment, and by clear and impartial writing much of the confusion. It must be remembered that in the days when he traveled accurate maps were unknown. Thus, in a map of the early eighteenth century, Chamonix is depicted as some sixty miles south of the Mont Maudite, the name by which Mont Blanc was then often known. Strange views indeed are to be found in the old writers, whose desire to be credited with universal knowledge allowed them little time for accuracy of detail. Crystals were supposed to be formed by the excessive pressure to which ice was subjected. One marvels that mountains do not sink into the earth by their own weight; another believes that they would certainly do so were they not hollow. Lakes well stored with fish were imagined to be present on the top of all high mountains. Besson, who wrote in 1786, was in advance of his time, but it is to be feared that he borrowed largely from De Saussure. He advocates the determining of mountain phenomena by direct observation and experiment. Gruner, in 1760, the year De Saussure first visited Chamonix, published a treatise describing accurately the main features of the results of glacial motion. Still in De Saussure's time the progressive movement of glaciers was questioned. The very foundation of scientific mountain craft lies in knowledge of glacial phenomena and of the results of glacial motion, and De Saussure proved these convincingly enough. Previously, the regular downflow of a glacier was often confounded with the increase or diminution of the mass of ice as a whole. De Saussure independently confirmed and extended Gruner's work. He distinguished clearly between the high snowfalls and the true glacier. He explained, too, the formation of moraines. Theory thenceforth was replaced by direct observation. The principle of the progressive movement of glaciers may now seem obvious enough. Yet for ages the moraines had stretched out their long lines, the dirt bands had traced their curves, the séracs had formed, leant over, toppled and fallen, the crevasses had started, widened and closed up again, but the interpreter had been wanting.

With De Saussure's geological work I have here no concern. Most valuable and interesting are his observations on the effect of high altitudes and diminished pressure on the human frame, for these have a direct import to the modern mountaineer, and to the mountaineering question of the day. De Saussure was the true type of the scientific mountaineer. Yet had it not been for the sensational exploit of the guide Jacques Balmat, in 1786, in ascending Mont Blanc, and had it not been for the wide interest that this feat evoked, De Saussure's work might have remained comparatively unnoticed, and it may be equally true that had it not been for such work as De Saussure's, few might have passed through the door which Jacques Balmat unlocked. Unquestionably the ascent of Mont Blanc marked an epoch. Probably there were quite as many in Balmat's day who would have questioned the possibility of ascending Mont Blanc as there are now who would question that of ascending Mount Everest.

De Saussure's observations on the law of the decrease of temperature in the atmosphere according to altitude are of the utmost value to mountaineers. The influence of cold as affecting the possibility of making higher ascents is a factor now recognized as of the first importance. For many years after De Saussure, little more was accomplished in mountaineering than repetitions of ascents of Mont Blanc.

Modern mountaineering dates its birth in the decade 1850-60. It was in 1856 that Tyndall first visited the Alps, ascending Mont Blanc the following year. Just as De Saussure's work was emphasized and supplemented by Balmat's achievement, so Tyndall's researches came opportunely during the active revival of mountaineering when the conquest of the great Alpine peaks was proceeding apace. Though Tyndall, like De Saussure, went originally to the Alps from purely scientific motives, he at once fell under the fascination and became an enthusiastic and a highly skilled mountaineer, which De Saussure never really aimed at. To very few will it ever be given to combine so happily the qualities of man of science and mountaineer which were so conspicuously shown in Tyndall, but to many it may be possible to work on the same admirable lines.

With the views which excited controversy at the time they were divulged, such as theories of glacial motion, and the viscous or non-viscous qualities of ice, I have now fortunately no concern. It need only be said, looking at the views that now obtain on this last question, that it is hard to perceive any ground for fundamental difference of opinion. The divergence of views really turned largely on the exact definition of a word. One feels almost inclined to echo John Hunter's well known condemnation of definitions. On one point there can be but little doubt; Tyndall's views fitted in admirably with practical mountaineering. He rendered clear and precise the interpretation of so many glacial phenomena that he almost made what is known as snowcraft—the most intricate, and the most valuable branch of mountaineering, for it is on excellence in snowcraft that the future of mountain exploration chiefly depends.

But the great influence he had on mountaineering was through his brilliant writings and lectures. Owing largely to these the glacial world began to attract the general interest which before had been confined to the few who had frequented and climbed the high Alps. This result was due to his admirable experimental methods and to the brilliancy with which he expounded his views, and it was in this theater mainly that the exposition was made. I may throw on the screen a slide, a view of the Weisshorn by Mr. Donkin, which almost epitomizes the lectures on "Ice, Water, Vapor and Air." Imagine that from the water in the foreground rises the vapor in solution. The warm air as it rises expands. The expansion produces cooling; as a result of the cooling the vapor is condensed and the cloud is formed.

Once formed, the band of cloud may remain stationary and of uniform size for a long time, constantly forming afresh on one surface, and as constantly diminishing on the other. Or the cloud may increase in volume. Following it then further in imagination till it becomes a rain cloud, the view shows the light fresh snow which has fallen on the higher flanks of the mountains. The snow sinks as the crystals part with their contained air, and so the mass by its own weight is pressed into firm snow, then into névé, then again into pure ice, which melts and flows away as a river. The circle is complete and the whole life history of a glacier is shown in this one view—not the less notable in that it is the presentment of the mountain on which Tyndall's greatest climbing feat was accomplished in 1861.

Time forbids any endeavor to repeat the more striking of the experiments shown to illustrate these pro-

* A paper read before the Royal Institution, February 15, 1895.

cesses, but I may bring before your notice once again the simple experiment first made by Faraday in 1850 to illustrate regelation. This simple observation on the properties of regelation was applied by Tyndall to the interpretation of many glacial phenomena. He showed that as the glacier passed through any narrow channel or was torn and fissured as it swept over the slopes or formed an ice fall that the ice was subject to crushing, and he demonstrated that pressure alone was sufficient to account for the complete remoulding of the mass, the closing of the crevasses, and the re-establishment of the purity of the ice. Unless snow possess these properties, all travel on the snow fields would be impossible.

When below the freezing point regelation does not take place. This fact, with regard to the highest ascents where the cold may be extreme, is of obvious significance. Under conditions of extreme cold, and where the snow contains little air, it will often be powdery, as was found on the first ascent of Chimborazo. This condition is rare in the Alps. In the latter, indeed, the worst conditions of snow seldom in the summer months turn back the mountaineer, but in higher regions, where time is of the first consequence, it would be of the greatest moment to judge beforehand in what condition the snow is likely to be found. The compass bearings with regard to the sun of the slopes up which the track lies, the prevailing winds and their temperature, the radiation from rocks in the neighborhood and such like factors must be taken into account. With regard to the formation of crevasses Tyndall did much work, though it was limited rather to the lower portion of the glacier and extended little above the ice falls. He showed most clearly the method of formation of crevasses, longitudinal, transverse and *oblique*. Many years previously Besson had said, "the ice of a glacier flows like a torrent following fluid laws," probably not appreciating the full truth of his own remark. Tyndall by careful measurement showed the situation of the point of maximum motion and demonstrated that when a glacier curved, the point of maximum motion lay nearer the convex border of the glacier. Thus in a glacier whose course is serpentine, the lines of maximum rate of motion crossed the central line at each curve. From this a practical point in mountaineering can be deduced. In descending an unknown glacier, it is generally best when the ice cannot be quitted to keep on the side of the smaller curve of the glacier when the marginal crevasses will be less numerous on this border. I can recall an occasion in the Caucasus when inattention to this point led to our being benighted on the glacier.

On the so-called dirt bands, first noticed by Prof. Forbes in 1842, Tyndall made many observations. It is matter for regret that a feature of glaciers so beautiful as these great curving stripes should have received so unpoetic a name. Tyndall clearly demonstrated their formation in the ice falls. To the mountaineer much that is practical may be gathered from their presence. Thus the existence of dirt bands shows conclusively that there must be an ice fall at some part of the glacier, and that there must be rocks in the neighborhood capable of yielding the grit of which the dirt bands are composed. Several glaciers may *coalesce* and form the main stream. Thus the Mer de Glace has three tributaries; on one, the Glacier du Géant, the dirt bands are strongly marked, on another, corresponding to the Glacier de Talèfre, they are but faintly indicated, while the third, the central stream, has no dirt bands at all. These several streams can be distinguished one from another, to the very extremity of the Mer de Glace, by the medial moraines. It is certain then that on two of the glaciers higher up will be found ice falls, and that the third, the central, will lead by more or less gentle declivities to the snow basins that feed it. Suppose the Mer de Glace were an unexplored field visited for the first time, such an observation might obviously be of the highest value in determining the route to be taken.

If it be true that with more accurate knowledge of glacial phenomena mountaineering skill has improved, and mountaineering possibilities extended, it would naturally be expected that the progress would be more shown in the class of amateurs, as they are termed, than in that of the professional guide. Such I think, and I have the authority of some first rate guides of long experience to back me, is the case. Much has been said on the comparative skill of guides and travelers. The truth probably is that the best guide of to-day is fully as good a man as the best guide of any other period, while the general standard of mountaineering proficiency among travelers has greatly improved, though there will probably be not a few laudatores temporis acti to question such a conclusion. Mountaineering has, however, developed in such a way that no comparison is possible now between the traveler and guide, and none is needed. For the more difficult work that yet remains to be done, the qualities that the guide shows best are absolutely essential to achieve the best possible success; and so also are the qualities that the traveler has in a great measure developed. The traveler and guide can each supplement the qualities of the other, and they who are interested in the progress of mountaineering ought be as much concerned with encouraging the development of guiding skill as of advancing their own. In one other respect science may possibly do much for the future of mountaineering by throwing light on the problems that still environ the question of the effect of high altitudes and diminished atmospheric pressure on man. Here the mountaineer comes in direct touch with the physiologist. The evidence gathered so far has come from three sources. Some from laboratory work, some from experience on the mountain side, and a certain amount from those who have made balloon ascents. So far, it must be allowed, the laboratory work has not been fruitful in practical results; but the question as recently revived is really still young. In the very few minutes that remain I may be able very briefly to sketch how the matter now stands, and indicate what progress has been made as to its practical solution.

First, as to the contribution of the mountaineer. On this diagram are indicated certain ascents, selected chiefly because in their description special reference has been made to the effect of high altitude on the travelers. The subject has for long received occasional attention. Sometimes in the early accounts surprise is expressed at the absence of effects which have for centuries been noticed and commented on. Thus Deluc on Mont Buet (10,200 ft.) seemed quite astonished that he did not suffer from mountain sickness. On Mont Blanc, De Saussure was considerably affected and gave an admirable description of the symptoms. De Saussure thought it improbable that scientific observations such as he wished to carry out could ever be properly made at so great a height—and now there is an observatory on the top, and a railway station, as I understand, is in contemplation. In the numerous accounts dealing with Mont Blanc published in the early part of this century, the effect of the rarefied air is almost uniformly mentioned. Often, it may be suspected, this was because the writer thought it proper to allude to the subject rather than because he really suffered from mountain sickness. Within the last few years the expedition has several times been made from Chamonix to the top of Mont Blanc and back to Chamonix within twenty-four hours; once I believe in about eighteen hours. The vertical height to be ascended is over 12,000 ft. In the ascent of Elbruz (Caucasus) one party experienced no discomfort at all, another party was affected. Of the more recent experiences in the Andes and Karakoram I need hardly remind you. Perhaps the Karakoram expedition shows the greatest height reached, though not much above the Schlagintweit expedition. A very curious point is brought out by the chart, viz., that heights far exceeding Mont Blanc had been reached long before the ascent of that mountain drew attention to the question. Thus the Karakoram Pass, about the height of Elbruz, has been known for centuries as a well established trade route, and another pass (the Changlung) of over 19,000 ft., has long been known. Indeed, Western people were still speculating on the possibility of ascending to any higher elevation than that of Mont Blanc, while centuries before in the East men had reached points nearly 4,000 ft. higher. Assuming that the highest point of the earth's crust is about 30,000 ft., this other diagram shows in another form how much has been accomplished by mountaineers, and, it may be added, how little apparently remains to be done. The question of the ascent of the highest point indicated (Kabru) on the diagram is doubted by many good authorities. There is no doubt about the height of the mountain which has been triangulated, but the question is whether the travelers did not mistake the peak they actually ascended. Whether the party actually did so or not, seeing that there is conflict of opinion, must remain uncertain. But the Karakoram experience, the latest, tends to show that it was certainly not physically impossible.

Experiments in the laboratory have been conducted with apparatus on a large scale similar to that which I show you here in miniature. By means of this apparatus the atmospheric pressure can be reduced to any degree required, and the pressure can be, by an ingenious contrivance, maintained absolutely constant for any desired length of time.

This apparatus has been devised for other purposes, but essentially it could serve like M. Bert's "pneumatic cabinet." You may judge, and judge rightly, that the conditions produced in a man who shuts himself up for a time in such an apparatus and lowers the pressure are different from those on the mountaineer. At least M. Bert's pneumatic cabinet has proved the existence of other factors in the problem. M. Paul Bert, experimenting on himself, sustained a diminished pressure equal to 32.528 feet for a short time—a lower pressure than that of Mount Everest. From many experiments he was led to the conclusion that deficiency of oxygen was the main cause of the symptoms—like those of mountain sickness—experienced. He set down the limit of life as arriving when the air contains but 7 per cent. of oxygen, the normal amount being 20 per cent. He was therefore led to infer that by supplying oxygen the evil effects of diminished pressure could be warded off. To carry a sufficient supply of oxygen on the mountain side would be physically impossible. Mr. Whymper's experiences disprove M. Bert's theory, and Bert's views received a further shock in the fatal balloon in which MM. Crocé, Spinelli and Sivel lost their lives, dying from asphyxia at a height of about 28,000 feet, although they had a supply of oxygen with them. M. Bert's researches have attracted much attention, but the work of Geppert and Frankel, published in 1883, really carried the question as regards laboratory work a good deal further. And here I hope I may be pardoned if I turn only for a moment to some physiological details. Geppert and Frankel found that life could be sustained, without supplying oxygen, at a far lower pressure, viz., that of 180 mm. of mercury, equivalent to a height of 36,400 feet. Yet more, they pointed out clearly that three distinct stages could be observed—that of difficulty of breathing, paralysis, and lastly, unconsciousness or coma. On the first and third much has been written. But it is the second of these three stages—the partial paralysis—which has received far less attention, that affects profoundly the question from the mountaineer's point of view. Geppert and Frankel's results seem absolutely trustworthy. They bear out, too, even allowing for possible error in observation, the experience of those who have ascended in balloons. Life unquestionably can be maintained at far greater elevation (i. e. at a much lower pressure) than that of the highest mountain. In the pneumatic cabinet, two most important factors do not come into play. No exertion is required beyond that of breathing, and there is no lowering of temperature. In high balloon ascents again no exertion is required of the lower limbs. The same effects that are shown under diminished pressure are also shown at greatly increased pressure. The circulation in the portion of the spinal cord or marrow immediately concerned with the innervation of the lower limbs becomes greatly disturbed. The partial loss of power in the lower limbs is brought about in this wise. The blood collects and stagnates at this portion. It has been stated, but incorrectly, that the reverse condition is produced. The temperature of all the extremities is greatly lowered, not only by the surrounding cold, but by change in the nerve centers themselves. The importance of this disturbance to the mountaineer who seeks to attain the greatest elevation on foot is obvious. Yet this, the most significant feature of the problem from the climber's point of view, seems to have attracted little attention. The actual effect of this partial paralysis must be to render each step which involves the raising of the weight of the body doubly or trebly as laborious as it would be at the pressure to which the individual is naturally accustomed. It is certain, however, that the effects can be completely recovered from, and this partial loss of power is, as far as can be judged from what is at present known, though a formidable obstacle and one not generally recognized, not insuperable. Possibly medical means may be discovered to combat the condition. Oxygen as a remedy has failed; other remedies may be found. Certain drugs recently introduced produce effects not unlike those which result from diminished pressure—a significant fact. One curious effect of diminished atmospheric pressure has been noted, and has been held to compensate for the diminution in the amounts of oxygen, a diminution that, as Professor Roy has suggested, must be increased on the mountain side when there is any melting of snow, inasmuch as water will absorb oxygen more readily than nitrogen from the air. If any stay is made at an elevation of some 13,000 feet, as Viault has shown, there is an enormous increase in the number of the red blood corpuscles, that is to say, an enormous increase in the area of the surface concerned with the absorption of oxygen. At the sea level the ratio of the body surface to the blood surface is as 1 to 2,560; while at a pressure corresponding to 13,000 feet the blood corpuscles so increase in number as the ratio of the body surface to that of the corpuscles has altered to 1 to 4,298. Putting the matter in another way, the actual corpuscle surface at sea level = 3,840 square meters; at 13,000 (after 11 days) = 6,144 square meters. But though the increase of the corpuscles may begin at once, the multiplication is a slow process. The maximum is perhaps reached in three to four days.

FUNERAL OF PROF. HUXLEY.

IN accordance with his own wish, the late Prof. Huxley was buried at the Marylebone Cemetery, Finchley. The coffin came up from Eastbourne in the morning, and the numerous mourners assembled at the cemetery to meet it. Wreaths from members of the family, and from friends and fellow workers of the great naturalist whose loss we mourn, covered the coffin. The Royal College of Science, with which Huxley was connected so many years, sent a large wreath, and there were also wreaths from Lady Hooker, Mrs. Tyndall, the members of the staff at the Royal Gardens, Kew, Mr. Herbert Spencer, Sir Henry Thompson, Sir Henry Roscoe, Messrs. Macmillan, and the editor of Nature, among others.

The funeral service was performed by the Rev. J. Llewelyn Davies, an old friend of Prof. Huxley's, now rector of Kirby Lonsdale, but formerly vicar of Marylebone, where he was for a long time Huxley's neighbor.

The family was represented by Mrs. Huxley, the two sons, Mr. Leonard Huxley and Mr. Henry Huxley, and three daughters, the Hon. Mrs. Collier, Mrs. Waller, and Mrs. Eckersley (the remaining daughter, Mrs. Roller, is in Switzerland with her husband, who is ill), Mrs. Heath (a niece), and two sons-in-law, the Hon. John Collier and Mr. F. W. Waller.

No announcements of the funeral were sent out, and the large number of distinguished men who attended, and the various learned societies that sent representatives, did so on their own initiative. The Royal Society was officially represented by Lord Kelvin, Sir John Evans, Prof. Michael Foster, and Sir J. Lister, many of the fellows also being present. The Geological Society was represented by Dr. Henry Woodward, Dr. Blanford, and Prof. Bonney. Dr. Frankland, Mr. Crookes, Dr. Thorpe, and Dr. Gladstone were the representatives of the Chemical Society. The mourners from the Royal College of Science included Prof. Rucker, Prof. Norman Lockyer, C.B., Prof. Tilden, Prof. Judd, C.B., Prof. W. C. Roberts-Austen, C.B., Prof. Howes, Prof. Farmer, Dr. Wynne, Mr. J. W. Rodger, and Mr. Woodward. Major General Sir J. F. D. Donnelly, K.C.B., Major General Festing, Captain Abney, C.B., Mr. T. Armstrong, Mr. F. R. Fowke, and Mr. A. S. Cole represented the Science and Art Department; Sir William Flower, K.C.B., Dr. A. Gunther, Mr. George Murray, Mr. C. E. Fagan, Prof. Jeffrey Bell, and Mr. F. A. Bather, the Natural History Museum; Prof. Armstrong, Prof. S. P. Thompson, Prof. Perry, and Prof. Ayrton, the City and Guilds Institute; Mr. Stanley Boyd, Mr. H. F. Waterhouse, Mr. J. F. Pink, the Charing Cross Hospital Medical School; Mr. J. J. H. Teall, Mr. F. W. Rudler, and Mr. E. T. Newton, the Geological Survey. In addition to the fellows of the Royal Society not included in the above, there were present Prof. E. Ray Lankester, Dr. Dallinger, Sir Joseph Hooker, K.C.B., General Strachey, Dr. Lauder Brunton, Dr. Sclater, Prof. Carey Foster, Prof. G. H. Darwin, Sir James Paget, Dr. Burney Yeo, Prof. H. Marshall Ward, Prof. Seeley, and Mr. F. Darwin. Among the other mourners were Mr. Walter Troughton, representing Mr. Herbert Spencer, who was prevented by illness from being present, Dr. T. K. Rose, Mr. W. Darwin, Mr. A. H. Heath, Mr. S. Highley, Mr. W. S. Stewart, Major General Sir Richard Pollock and Mr. D. Pollock, Mr. Alma Tadema, Mr. W. E. H. Lecky, Mr. and Mrs. Humphry Ward, Mrs. Tyndall, Mrs. W. K. Clifford, Mr. Henry James, Mr. Mark Judge, Mr. H. Saunders, Dr. Semon, Mr. F. Macmillan, Mr. G. L. Craik, Mr. Clodd, Mr. G. Griffith, Lady Staveley Hill, Mr. Paynter Allen, Mr. John Boyes, Mr. Spencer Walpole, Mr. Woodd Smith, Dr. J. Johnson, Mr. James Hulme, Mr. Stanley Edwards, Dr. Glover, Mr. T. B. Windsor, the Rev. D. D. Jeremy, Dr. J. Malecki, Mr. J. Spiller, and Mr. and Mrs. Briton Riviere.

The funeral was at first announced to take place at 3 o'clock, whereas the time fixed upon was 2:30. Owing to a delay in the train, a number of workers in science, from the Midlands and the North of England, did not arrive at the cemetery until the ceremony was over, and thus, to their deep regret, they were deprived of the melancholy satisfaction of being present when the remains of an esteemed master and friend were laid to rest.

The memory of Huxley will always be cherished among men of science, and it is imperative that there should be a permanent memorial of some kind to show the world how great is their regard for him. The memorial should be a truly national one, and not limited to any particular institution. We understand that the Dean of Westminster is willing that a tablet shall be erected in the Abbey, if desired, and this is one of the forms which the memorial might take. Sir Wil-

liam Flower suggests another form, in a letter to the Times. He writes:

"In the great hall of our national Museum of Natural History the noble statue of Darwin will hand down to posterity the image of the man as he appeared to all who knew him in life. Near this will soon be placed another statue remarkable for the accuracy with which the striking personality of Owen is represented, as all who see it now at the Royal Academy Exhibition can testify."—Nature.

COVERED WAYS OF HARDY FRUIT TREES.

THIS quite practicable way of growing fruit trees and shading walks is too seldom carried out. Few things would give more satisfaction if the right sort of fruit trees were selected, and by the right sort we mean kinds of the highest excellence, which do well in their several districts. Although in gardens generally the shaded walk is not nearly so necessary as it is in Italy and Southern France, or even in the warmest parts of Germany, in a season such as the present shade is as welcome here as anywhere else, and as many of our garden designers in their wisdom have given us four times as many walks as anybody wanted, there is plenty of opportunity for covering some of them with fruit trees, which, well chosen, would give us much beauty in spring, handsome fruit in autumn and shaded walks. The very substance of which walks are made lends itself much more to the wants of fruit trees than the soft surface of the ordinary kitchen garden, so that by this kind of fruit culture we use, as it were, the walk itself and use it well. Anybody who notices the apricot district of Oxfordshire and the neighboring counties may see how well fruit trees do in hard walks. It is not only in kitchen and fruit gardens that such a thing would be desirable, but even in flower gardens, if we could ever get out of the strait-laced notion of a flower garden which insists on everything being seen at one glance. There is not the least reason why a

COVERED WAY OF FRUIT TREES.

beautiful arbor of fruit trees would not be most effective and welcome in various kinds of flower gardens associated with hardy flowers, or otherwise. In some old English gardens there was a habit of "plashing" trees over walks—that is to say, growing trees like the lime over walks, which naturally grew so vigorously that they had to be repressed with an equal vigor, and this led in the end to ugliness in the excessive mutilation of the trees, as may still be seen in some old gardens. One result of the frequent cutting down was a very vigorous summer growth of long shoots, which cast a dense shade and dripped in wet weather. Even apple trees may be trained over walks, and will support themselves without wires or any structure, as we once saw a perfect covered way of them in a Sussex garden. We think the purpose of such walks would be equally well answered by training fruit trees over them, as they are trees which much more readily submit to such treatment and give the light and airy shade which is best in our country.

In choosing the kinds of hardy fruit trees for this purpose, the first place should be given to the best British apples, which are as handsome in the early year as in the fall, and give the best fruit which our country can produce. The advantage of trellis training is that, the shoots of the tree being fixed, they escape to a great extent injury from storms, which are so frequent in the autumn, and if we get a crop of fine fruit, it is more likely to come to maturity in this way. The very hardiest kinds of pear, plum, and cherry also would do well in this way, and small fruits might be easily grown to perfection. Moreover, if the very finest kinds of small fruit were grown in this way, it would be possible to protect them easily. The trellis, whatever it was formed of, need not be confined to fruit trees only, but here and there wreaths of clematis or other elegant climbers might vary the lines.

Mrs. Newman, who sent us the photograph of the covered way of apples from which our engraving was made, says: "The trees are trained upon iron supports, and they bear a quantity of fruit. When in full flower, with a border of pansies and forget-me-nots at their feet, and the distance of hill and valley beyond, they are a lovely sight." In this case, as we suggest, fruit trees have been used with excellent results in the flower garden or pleasure grounds. The photograph was taken in the garden of Mr. W. Jackson, at Haslemere.—The Garden.

[FROM KNOWLEDGE.]

THE SUGAR CANE.

By C. A. BARBER, M.A., F.L.S. (late Superintendent of Agriculture of the Leeward Islands).

IN the year 1892 the world's production of sugar was estimated at close on fifty million hundredweight. It may be broadly stated that of this quantity half is obtained from the sugar cane grown in the tropics and half is extracted from the beet root of the temperate region. Sugar is also produced from sorghum, the maple, several palms, and from starch; but these sources may be neglected in a general estimate.

The consumption of sugar varies very greatly in different countries. Thus it is calculated that the inhabitants of Great Britain and Ireland require seventy-two pounds per head annually, the quantities used by other countries being fifty-two pounds in the United States, twenty-five pounds in France, and only seventeen pounds in Germany. To us, then, as a nation, the physiological action of sugar upon the system is a matter of considerable importance. When first introduced into Europe it played a prominent part in medicine, and it would be interesting to turn up the old medical works to see what it was used for.

To-day it is a conspicuous article in our diet, and its true value as a nutritive substance is becoming more and more widely recognized. Interesting experiments have quite recently been carried out in schools, as to the effect of adding several ounces of sugar daily to the diet of the boys: the result being that they are found to be capable of performing an increased amount of muscular exercise. Be that as it may, the effect of unlimited quantities of sugar cane juice upon the laborers on West Indian estates is seen every time the crop is reaped. However weak and starved looking the negroes are when the first canes are cut, they rapidly improve in condition; and although the labor in the field is exceedingly heavy, toward the end of crop time they are conspicuously sleek and well fed. They are daily met carrying home a fine cane or two upon their heads as perquisites.

Wray, a writer upon the sugar cane, asserts that it has been absolutely proved that man can not only exist but become stout and healthy on sugar and sugar alone. He instances the case of the crew of a ship bringing home a cargo of sugar from the tropics. By calms and disasters, provisions ran short and were at last absolutely exhausted. The starving crew had recourse to their cargo of sugar. This not only sustained the men, but actually cured them of the scurvy, which had made sad havoc among them. Supplied by this providential food, they reached their port in safety.

Of the main sources of sugar supply, the beet root was first grown for this purpose barely one hundred years ago, while the cultivation of the cane is known to have been carried on before the Christian era. We know that several centuries before Christ the cane juice was sucked or expressed in India, although the art of making solid sugar seems to have been discovered much later. The plant is not known to occur wild in any part of the world—a fact which, of itself, points to great antiquity—and it is accordingly difficult to determine its original habitat. The name is, however, derived from the Sanskrit Sarkura, and more recently the Arab Sukhar; and from this and other facts, it is deemed likely that the plant was originally obtained from the coast of India north of the Indian Ocean, or from the mountains of Polynesia in the neighborhood of the tropics.

Unknown to the ancient Jews, who used honey for the sweetening of their food, it was first used in Europe by Alexander the Great, who, in 327 B. C., brought it as one of his trophies from the East. Thus Pliny relates that Alexander found "a remarkable kind of reed, growing in India, which produced a sort of honey without the assistance of bees."

The cultivation was introduced into Persia about 500 A. D., and great attention was at once paid to the manufacture of this valuable substance. We read now for the first time of really fine white sugar—"axhewn" as it was called. This was obtained by repeatedly boiling, straining, and refining with milk. The Arabs obtained the plant on their conquest of Persia, and carried it westward with them. In 750 A. D., it is stated that the most fertile land in Egypt was almost entirely under sugar cultivation, and the manufacture of sugar increased largely. It is said that, at marriages and festivals at the Arabian court in Egypt, quantities of sugar were consumed on individual occasions amounting, in our reckoning, to from sixty-seven to seventy-one tons—the annual yield of a small estate. About the same time it was introduced into Spain by the Moors.

Next in its westward course the cane was carried to the Canaries, while in 1493 Columbus took it to San Domingo, where it increased so remarkably as to become in after years the main cultivation of the West Indian Islands. And so it continues to be at the present day, after the lapse of four centuries.

The sugar cane is now cultivated within the tropics in both hemispheres, especially in the West Indies, Java, Mauritius, the Sandwich Islands; also in Egypt, Queensland and the Southern United States. In America its northern limit is 32°, in China 30°, while it is grown in individual gardens in Spain as far north as 37° of latitude.

There is no more beautiful sight in the tropics than a sea girt coast clothed by cane fields. In some islands—for example, St. Kitts and Barbados—there is no other cultivation, if one omits the smaller patches of vegetables grown for local consumption. In all directions one sees field after field of canes in every stage of growth, from the young plants just emerging from the black soil to the waving feathery "arrows" of the mature plants, with here and there the tall chimney of the half-hidden cane mills. The feeling of novelty experienced on driving for the first time through these gigantic grass fields—for the cane is a grass—is not easily forgotten. Shut in by an avenue of reed-like stems and waving leaves, one receives a lasting impression of the luxuriance of tropical agriculture; and, while fighting one's way into the cane fields in search of the various pests by which the plants are just now so abundantly attacked, one sympathizes with the ants at home which may be seen climbing about among the grass stalks.

The sugar cane, as already mentioned, belongs to the order of grasses—the Gramineæ of botanists. The following is a brief botanical description. Each plant consists at crop time of a much-branched underground root stock, which gives off a tangled mass of thread-like roots below and a bunch of from ten to eighteen aerial shoots above. The latter, from six to fifteen feet in height, may be roughly divided into two portions—the lower part, from which the leaves have dropped or are readily detachable, called the "cane," and the upper younger part or "top." The canes are cylindrical and jointed, and of various shades of green, yellow and purple, sometimes variegated with beautiful stripes. Those of ordinary cultivated varieties are from one to two inches in diameter, with joints from one to eight or nine inches in length. The broad, strap-shaped leaves arise in two opposite rows from the cane, one from each node or knot. They are from three to six feet in length, with a diameter of one to three inches. Each leaf is divided into two parts—a lower shorter portion, the sheath, usually of the color of parchment, which completely embraces the stem and is attached all round the node, and a much thinner flat blade of bright green, with a white mid-rib, or "bone," in the center and a finely-toothed edge. The sheath is in some kinds thickly covered on the outside with long siliceous hairs, which readily penetrate the skin, while very severe cuts are sometimes received from the saw-like edges of the blade. In the axil of each leaf, at the joint, and therefore completely protected by the sheath, is a solitary bud. Any bud upon the plant may be used for propagation, and will, under suitable conditions, reproduce the whole plant. At the joint, and on each side of the bud, is a zone of several rows of small circular prominences, which completely encircles the same. These are the adventitious roots, which in contact with damp earth at once develop and cause the bud to burst into a leafy shoot. In the ordinary upright canes these roots remain dormant, but when canes are beaten down by high winds, or bend by their own weight, they frequently become fixed to the ground. A cane dug out of the mud in Dominica was found to be nineteen feet in length and extensively rooted at every joint. At the upper part of each joint, just below the insertion of the leaf sheath, there is usually a ring of white waxy substance coating the surface of the cane.

The cane, or lower part of the aerial shoot, is of importance, as from it alone is obtained the sugary juice. It is solid, as contrasted with the hollow bamboo; the exterior, or "rind," is hard enough to turn the edge of an ordinary penknife, but the interior is soft and juicy. At maturity the leaves have fallen off.

The upper part of the shoot, or "top," is made up of immature joints. These are much shorter than in the cane and contain no sugar, or very little. The leaves are all still attached and form a beautiful green plume. This part of the cane plant is much attacked by caterpillars of different kinds.

The sugar cane is usually reaped before it flowers. The solid stems are carried to the mill to be crushed, while the tops are saved for planting next year's crop, and the surplus used as food for the cattle. But if, instead of being cut, the plant is allowed to grow on for a few weeks, each shoot will throw up an inflorescence or "arrow." Although the sugar cane is vegetatively reproduced in ordinary cultivation, and seed is not used, the flowering of the plant is a matter of some consequence in agriculture, as thereby the yield of juice is perceptibly diminished. In this matter there is great diversity of opinion among planters. In some places the appearance of much arrowing among the canes is looked upon with indifference, while in others it is regarded with apprehension; and again, it is found that the varieties of cane behave differently. The Caledonian Queen, for instance, is much more prone to arrow before reaping than the Otaheite, as it reaches maturity sooner.

For those not immediately interested in the yield of juice, the inflorescence of the sugar cane is a very beautiful object indeed, and few sights in the tropics are more striking than a field of arrowing canes. A considerable trade might doubtless spring up if the heads were cut and prepared so as to prevent the scattering of the flowers. Each inflorescence is a pyramidal mass of feathery florets, supported by a shaft or stalk from four to six feet long.

It will be of interest briefly to trace the growth of

the cane plant from sowing to reaping. The method of propagation universally adopted in the field is that of burying in the earth pieces of the stem bearing undamaged buds, which are then called "plants." Such is the vitality of the plant that the buds thus treated rapidly shoot out, giving off roots at their bases, and becoming independent plants almost before the decay of the piece of parent stem. The part of the stem chosen for planting is usually the top, although almost any part with sound buds would do. The advantages of choosing this part are that there is comparatively little sugar in it, and therefore there is no loss in the quantity of sugar obtained from the crop: the buds are closer together, and there is thus a greater chance of obtaining a good stand; and, lastly, the buds of this portion of the cane are probably in a more plastic condition. Not infrequently, however, the canes themselves are cut up and laid down, sometimes in long furrows, as in the United States, at other times freely scattered over the soil and covered up, as in parts of India.

When the crop is reaped in the West Indies, before the canes are carted to the mill, the tops are cut off and left upon the field. A separate body of workers come round, collect the undiseased tops, and trim them for planting. Pieces are selected from six to eight inches in length, including on an average three buds. These are neatly arranged in baskets and carried to the liming tank. Here they are immersed in a mixture of lime and water for about twelve hours, to free them from unobserved caterpillars, etc., and it is quite surprising what a number of these creatures are seen shortly afterward wriggling on the surface of the water. After immersion they are spread out in the sun for an hour or so to dry, and are then ready for planting.

The soil of cane fields is usually kept in a fine state of tilth to the depth of nine inches or more. This is greatly facilitated by the presence of quantities of decaying vegetable matter in the shape of the cast-off leaves and dead roots of the previous crop of canes.

After the field has been cleared of canes for the mill, of tops for the plants and fodder for the cattle, and finally of the diseased pieces which have been cast aside in the bustle of cane cutting, the new cultivation is commenced. The whole field is still covered by a thick layer of dead leaves or "vowra." The first operation is the "ranging" of the vowra, or drawing it over the stumps of the canes just reaped. A gang of laborers is then told off to dig a series of parallel furrows about five feet apart, throughout the entire field. The furrows are dug between the rows of last year's stumps and the soil is heaped upon the masses of vowra. The ridges thus formed, or "banks," are broken up by a plow after a few weeks, and the decomposition of the vegetable matter contained adds to the humus, so necessary to the growth of the canes.

After the furrows are prepared the "cross-holing" is done. A few dexterous strokes of the hoe—which is almost the only agricultural implement in the negroes' hands—build a narrow ridge across the furrow, to be followed by another and another till the whole field is honeycombed with a multitude of square pits. The centers of these "cane holes" are about five feet by *five apart*, although the distance varies with the locality and the kind of cane. The cross-holing is intended to collect the rain and supply the young plants with moisture, and consequently, in wet regions, they are dispensed with, the furrows becoming rather a system of drains for carrying off the superfluous water—canes cannot stand stagnant water.

It is usual to add to each hole a small supply of stable manure, "pen manure" as it is called; but the quantity available is rarely sufficient to provide for the entire acreage of "plant canes" every year. The fields are treated in succession, so that each has its supply of pen manure once every few years.

The pieces of canes selected for propagation, or "plants," are pressed down in a slanting position in the bed of the cane hole. In a few weeks the tender green blades appear, and the cane growth has commenced. While the young plants do not cover the ground constant weeding is necessary, and, in the case of lighter soils, a "cultivator" may be driven between the rows. But the dense mass of cane leaves quickly covers the ground and effectually strangles any unbidden growths.

It is necessary from the first to be on the lookout for dying shoots or "dead hearts." These are shoots which rather suddenly turn brown and die. They are the sign of the progress of the moth borer, which works its way upward till the growing apex is reached, when all growth is checked and the part commences to rot. All dead hearts are persistently cut out and destroyed, for fear that the caterpillars should turn to moths and spread the disease.

Meanwhile the plants are growing apace. Instead of one or two shoots from each cane hole, we now see six or ten, the number constantly increasing with the age of the plant. The shoots in the "bunches" grow for some months before any solid "canes" are formed. This depends to a very large extent upon the season. If the desired rain is too long withheld, no cane is formed at all by crop time, and the field is not worth cutting. This is, however, not frequently the case. Although the seasons vary considerably, the rainfall in the tropics is a fairly reliable factor in cultivation. There are, of course, "dry" islands, generally such as have no great elevation. Antigua, for instance, with a maximum height of some one thousand three hundred feet, is liable to droughts. One such occurred in 1894. The average rainfall may be taken as from forty-five to fifty inches per annum. On one estate, in the windward part of the island, nine or ten inches were recorded in 1894 in as many months, a quantity with no appreciable effect in the fierce heat of the tropical sun. It is not surprising, then, that even the cactus began to wither, and every cane plant upon the estate died.

The rainfall is very carefully studied in the drier sugar-growing islands. Certain stages of the plant's growth require a much greater rainfall than others, while near crop time it is preferable to have dry weather, for the ripening of the canes. The absence of rain during the growing season appears also to be a direct encouragement to nearly all the pests which attack the cane plant, and this has been markedly so during the last few years in the West Indian plantations.

We have thus traced the cane plant in its growth from the dormant bud to the full-grown "bunch," with its knotted root stock and mass of solid upright canes. In very few islands is the growth of the cane confined to one season. Where the soil is not too light, and a fair amount of rain is obtainable, it is usual to allow the plants after being cut down to shoot out again or "ratoon." The expenses of cultivation, which, in the northern West Indian Islands, at any rate, is largely performed by hand, are so great that the economy of ratooning is at once evident. Unless the conditions are very favorable, however, this system of ratooning cannot be employed for more than two or three years. As remarkable exceptions, fields may be seen in Nevis of ratoons of ten to fifteen years' standing. In Dominica again, where the cultivation is in a very backward condition, on one estate, whose fields are occasionally swept by the fertilizing waters of a turbulent river, it is impossible to determine when the fields were last planted—probably twenty-eight or thirty years ago. Such is the fertility of the soil, kept up by the alluvial deposits of the overflowing river, that year after year the cane may be reaped at a profit, and shows no tendency toward dying out. In the neighboring island of St. Kitts, which is dry and possesses an exceedingly light soil, by way of contrast, only certain fields can be successfully ratooned at all, and second ratoons are a rarity.

The reaping of "ratoons" and "plant canes" is identical. A gang of negro laborers is turned into the field, armed with cutlasses—heavy iron blades a couple of feet long and broad in proportion, fastened to a short wooden handle, to give a firm grip. A single blow severs the cane low down, and a second cuts off the top. The cut canes are rapidly collected into bundles and tied together with wisps made of the strong green leaves.

The bundles are hurled up and stacked into the lumbering ox or mule drays, which crash along the lanes to the mill yard, amid the shouts of the drivers and the cracking of whips. The negro is nothing if not noisy. Each load is thrown in a heap on the ground near the mill, and when thirty or forty have been deposited the "mill gang" start their work.

The canes are placed endwise between massive iron rollers, made to revolve by powerful machinery. The canes are thoroughly crushed, a mere residue of fiber emerging from the rollers and streams of dirty juice escaping below. The cane fiber, or "megass," is quickly carried away in baskets and spread in the hot mill yard to dry. When quite dry—a matter of three or four hours in the burning sun—it is collected into heaps for future use. It supplies the fuel for the boiling house, and it is difficult to understand how it could be replaced in the absence of all trees and the costliness of imported coal.

It would occupy too much space to follow all the details of the "boiling house." Many are the processes through which the juice of the cane passes before it is changed to the beautiful brown crystals or white cubes which we purchase at the stores, or the rum bearing the Jamaica brand. The processes, indeed, are many and complicated, but the principle is the same as that by which the Persians many centuries ago produced their "ax-hewn" product. After "tempering" with lime and boiling down, the crude juice is run into flat wooden troughs to cool. Here it sets into a dark brown mass of wet crystals. By rapidly rotating these in "centrifugals" the molasses present is driven out, and a refined product obtained which is fit for the table.

The West Indian plantations, with which the present article has mainly dealt, are at present in a very depressed condition. The energetic competition of the beet-growing European countries, rendered more formidable by enormous bounties, has reduced the margin of profit to the narrowest limit. Add to this the fact that diseases of a new and severe type have recently made their appearance in the cane fields, and the outlook becomes one of gloom. It is, indeed, at the present moment questionable whether the cultivation of the cane in these beautiful and smiling islands can be continued. It depends to a large extent upon the beet bounties. If the people of France and Germany can support the heavy taxation which has been recently suggested, the whole cultivation of the cane and manufacture of its product will need revision.

The question of cane diseases has engrossed much attention of late years. Added to the depredations of insects, which have been known for centuries, fungous pests of a much more deadly character have made their appearance. Of the many canes under cultivation in the West Indies, the variety usually grown, the Otaheite or Bourbon, is much more severely attacked than some others. There are what appear to be "immune" canes; and one immediate remedy, which has been extensively adopted in St. Kitts and Barbados, is the substitution for the Otaheite of some such cane as the Caledonian Queen.

A great stride has been taken during recent years in another direction. The canes have been propagated from time immemorial by vegetative means, i. e., by putting in pieces of the parent plant, so much so that the fact had apparently been lost sight of that the seed of the arrow is occasionally fertile. The discovery of the possibility of raising canes from seed is a matter of recent years; and it is hoped by this means to reconstitute the plant, to impart to it a vigor and capacity for resisting disease, and at the same time to increase its sugar-producing properties.

But the path is long and laborious; the obtaining of fertile seed by the crossing of varieties is a matter of no ordinary difficulty, and, once obtained, two years must be passed through before the first canes can be reaped and tested. The vast majority of seedlings thus raised are of comparatively little value, and it is only here and there that one is found which is considered worthy of further trials. Then it has to run the gauntlet of diseases, besides entering into competition with the most approved sugar-producing varieties—the products of selection acting through twenty centuries. Trials have, however, been conducted in many places—Java, Mauritius, Barbados and Demerara—and the laborious work of Prof. Harrison in the two last-named colonies is a monument of patient and scientific application. With continued experiments of this character, an improvement is certain, judging by what has been done in other cultivations by seminal selection; but the tedious nature of the operation will of itself serve to deter other colonies, less fully equipped with the means of carrying on the experiments, from proceeding with this important work.

[Boston Commonwealth.]

A VISIT TO BASSAE.

Twenty-two hundred years ago, so the story goes, a great plague visited Greece and many people died of it.

One place, however, was left untouched, the little town of Phigalia, in Arcadia. Now the plague was a grievous one and sore, and the Phigalians were grateful for their deliverance, which could be traceable to no other cause than that Apollo, the god of the sunlight and consequently of health, had signally favored the inhabitants. So to Apollo, in their gratitude, they turned and would build him a temple. The temple must be a fine one, and none but the greatest artists should build it. Now, great was the fame of Iktinus, the architect of the Parthenon, and to him they sent; and he came and built a temple with thirty-eight columns of strong Doric around it and ten Ionic half pillars of great grace within. To decorate it the greatest masters of the time were summoned, and a glorious frieze with the historic battle of the Centaurs and Lapithæ and of the Greeks and Amazons, with wonderful curling drapery, soon surrounded the walls. A fit spot for this had been chosen, high upon a mountain pass whence the noble air and sky loving god could survey all the territory of his chosen people.

Such is the legend of the founding of the temple whose remains form perhaps the most imposing if not the most beautiful of Grecian ruins.

To reach it we were perforce obliged to make quite a pilgrimage. The starting point is the charming mountain town of Andretsaina, itself high up on the slope commanding a superb view all over the northern Peloponnesus. From there we betook ourselves early in the morning to horses, mounting the wonderful Greek saddles, which, perhaps, considering the road, are quite as comfortable as European ones. High before and behind, they afford some support on the tremendously steep grades. The little horses are marvelously sure footed, and really one is safer on horseback than on foot.

The road starts straight up the mountain and is soon high above the village. Who can describe the beauty of these Greek mornings? Range above range of mountains, each with its own peculiar tone of azure blue, stretch away in the distance. In the foreground are green hills with groves of live oak, blooming with clematis and waving in their little level spots with ripening grain. Little cool streams flow merrily down, making a delicious sound as they run. Above is the sky so blue, a blue it only has in Greece, and a few fleecy clouds rise from the mountains as the morning grows older.

The sun shines brilliantly, and yet in these high altitudes it does not get oppressive even at noon in June.

Over two high passes the path goes, and after two hours of riding we come suddenly in sight of the temple. It is impressive, so still and silent, so far away from any house of man; so dignified, and yet so graceful; and coming as it does all at once into view, it almost startles one.

The temple itself is one of the best preserved in Greece and it is one of the most satisfactory. It has escaped Macedonian and Roman reconstructions which, while very beautiful at the time, are a great nuisance to the archæologist by covering up or taking away the earlier and more truly Greek originals. It escaped Christian fanaticism, which with its barbarous iconoclasm sought to do away with all traces of the beautiful religion of the Greeks. Perhaps it is peculiarly fitting that Apollo's temple should have been preserved, as his worship, that of the bright sun god, that of light and beauty, is one particularly fascinating to the modern Christian.

His temple has escaped the hordes of Slavs which swept over the country and almost obliterated the ancient Greek stock. The Franks and Venetians and other mediæval nations did it no harm; they cared so much for fighting each other and making themselves impregnable fortresses on impossible hills, that they had no time to admire the beauties or to combat the superstitions of a softer age unsympathetic with their own. It has escaped the Turks, who prefer to vent their fanaticism on the present Christians rather than on relics of a religion past and gone, and who were too indifferent to care one way or another about the ancient buildings if they were not suitable for a mosque or for a powder magazine.

It has been spared by the later Greeks, who find the marble and limestone ruins so convenient for their limekilns and who have done countless damage in nearly every place simply through gross ignorance. Even when they learn that ancient remains are important, they conceive the idea that in each piece of marble is a treasure, and they take great pleasure in smashing valuable fragments only to raise false hopes for the next. Lastly, the weather and earthquakes which have done so much damage in other places have spared this spot.

There stands the temple, with thirty-five out of the thirty-eight columns still in position to their full height. It is very long for its width, having fifteen columns on the sides to six on the ends, a proportion quite unusual in Greek temples of that age. The color is a smooth gray, there has been no dust to turn the stone brown as at the Parthenon, nor salt breeze to bleach it as at Sunion. But it is all harmonious.

Inside, besides the vestibules at each end, there were two divisions of the cella; the larger had a row of very graceful Ionic half columns jutting out from the wall, five on a side, so as to make little alcoves something like the chapels in a church. The effect must have been very pretty.

This combining of the Doric and Ionic seems quite harmonious here. Outside, the solid Doric standing with the air and sky, themselves Doric in their simplicity, for a background; inside, the more slender and artificial Ionic invites close examination by its greater detail of base fluting and capital and is in keeping with the smaller proportions of an interior. It would be well if some of our modern architects with a taste for combination had some such logical basis for their inharmonious designs.

The other part of the cella seems to have been a

tiny temple in itself, originally with an entrance to the east and an Apollo statue to the west, around which as a nucleus the greater temple was built with the length of the former for the breadth of the latter. This may account for the peculiar orientation of the temple, the long axis being from north to south, an example not elsewhere duplicated.

The lovely frieze is now in the British Museum, having been unromantically sold to that government at the beginning of the century. When in Greece, one sees the justice of the law forbidding any art treasure to be taken out of the country; it is bad enough to see the temples stripped of their glory and the tombs of their treasures, without thinking of these away off from their native land in London, Paris, or Berlin.

The view from the temple itself is fine enough; but from the little mountain to the northwest the whole panorama of the Peloponnesus is opened. In succession, Achaia, Elis, Messenia, Laconia, and Argolis are visible, each with its massive mountain ranges. Arcadia lies at our feet, with countless rows of hills and fertile valleys between. To the west, the splendid curve of the Ionian Sea along the coast of Elis stretches, with the deep blue haze above and beyond it.

The most conspicuous objects are, however, Ithome and Taijgetus. Ithome, a massive table land in the midst of a great plain, looks built by nature as a place of refuge for the poor peace-loving Messenians when pursued time after time by the relentless Spartans. Taijgetus—Pentedaktylon (Five finger) as it is called—is the type of the Sparta it overshadows. Alone and silent, the highest mountain in southern Greece, it is like the proud, haughty, silent Spartan, refusing to bend to till the soil or to ease himself that he might feel comfort. Mighty, bare, snow-covered, alone, stands Taijgetus, a monument to the Lacedemonians, than which, had they their say, they would have chosen no other.

Unwillingly we quit the summit and wend our way down to where the tempting smoke indicates that Georgios, our faithful courier, guide, cook, and sage adviser, has prepared a delicious hot breakfast, which we eat in the shade of an old, sturdy tree. A nap follows, else were we not true Greeks, and later the gathering clouds sweeping over and under us and the increasing chill reminds us that even in Greece cold is a fact at an altitude of 4,000 feet.

So, with a last view of the grand old temple, we descend to cozy Andritsaina, enjoying, as we enter, the glories of a Greek sunset in a symphony of violet.

Poros, June 30, 1895. CHARLES PEABODY.

BICYCLE GEARS.

ONE of the most perplexing questions among wheelmen is that of the relations between the gear and the pedal crank of a wheel. In order to understand them some mathematical explanations are necessary. The gear of a safety having wheels twenty-eight inches in diameter is arrived at by dividing the number of teeth in the large sprocket by the number of teeth in the small sprocket, which is on the hub of the rear wheel, and multiplying the quotient by the diameter of the wheel—e. g., 18 (teeth of the large sprocket) divided by 8 (teeth of the small sprocket) equals 2¼, multiplied by 28 (diameter of wheel) equals 63, the diameter in inches of an imaginary wheel, each revolution of the pedal of which would cover a lateral distance of 16·48 feet.

The radius of a wheel is known as the long arm of the lever. The pedal crank proper, irrespective of its length, is the short arm. The shorter the short arm or pedal crank, the more weight is required to balance the end of the long arm wheel, the imaginary projection of which terminates at the rim of the wheel. As the pedal crank is increased in length, the weight or power required on the pedal is diminished. For instance, a wheel geared to 63 inches with pedal cranks 6½ inches and bearing a pressure on the rim of the wheel of one pound, requires 4·85 pounds pressure on the pedals to balance it; with the same gear and wheel, and 8 inch cranks, the necessary pressure would be 3·875 pounds. The 6½ inch pedal crank in making one revolution covers a lateral distance equal to 40·8 inches and propels the wheel a ground distance equal to 197·9 inches, while an 8 inch crank in making one revolution covers a lateral distance of 50·26 inches and propels the wheel 197·9 inches. Thus the distance covered by the wheel is the same whether a 6½ or an 8 inch crank is used, provided the gear is identical. In other words, the difference is in the power employed, not in the practical results. The 6½ inch crank needs 4·85 pounds and the 8 inch crank 3·875 pounds. But while with the 8 inch crank there is less exertion to move the weight, with the 6½ inch crank the foot travels 9·42 inches less in driving the wheel the same distance. That this saving of foot motion on the short crank equals the saving of force on the long crank appears from the following calculations:

The circumference of a wheel of 63 inch gear is 197·92 inches; the circumferences of the circles described by the foot on a 6½ inch and an 8 inch crank are respectively 40·84 and 50·26 inches. Analysis of these figures shows that each inch traveled by the foot produces a progression of the wheel of 4·84 and 3·94 inches respectively. The apparent gain by the long crank in power is, therefore, nullified by the greater foot motion.

This is merely the application of a well established law of dynamics, that power and speed are interchangeable. While on a bicycle of 63 gear and with a 6½ inch crank 4·84 pounds are required to overcome one pound of resistance and a pressure of that amount by the foot traveling through one inch of space produces progression of 4·84 inches, a pressure on an 8 inch crank of only 3·93 pounds overcomes the same resistance, but as a result of one inch foot motion yields only 3·93 inches of progression. The question, therefore, takes this practical shape: As the average man cannot adapt himself to that stroke of pedal which is easiest for the man of abnormal strength and reach, he must be fitted with a crank best suited to his powers. Years of experiments have resulted in the selection of the 6½ inch crank as the standard for men and the 6 inch crank as the standard for women by nearly all the manufacturers of wheels as being best for the greatest number of riders, as builders have adopted a uniform rise in stairways to which people have become so accustomed that a difference of half an inch is immediately noticed. A mechanical equivalent of an 80 inch gear with an 8 inch crank is a 6½ inch crank with a 65 gear, the same power being expended in both cases. A low gear is a great help when resistance is great, but entails rapid foot movement on levels. A high gear is easy on level, hard roads, giving rapid progression with slow foot movement, but overtaxing the strength on up grades. A bicycle is a road engine driven by human power and comes under the same laws as a locomotive. Freight engines have low gears in the sense that the cranks are comparatively near the rims of the driving wheels, while express locomotives have a short stroke, or what would represent high gear in a bicycle.

The following table will explain itself:

Gear		63	72	76	80
6½ crank	Proportion	4 11–13 to 1	5 –13 to 1	5 11–13 to 1	6 2–13 to 1
8 crank	"	3 15–16 to 1	4½ to 1	3¾ to 1	5 to 1
6½ crank	Pressure	4·85	5·54	5·85	6·15
8 crank	"	3·37	3·84	4·5	5·00
6½ crank	Ground covered by large wheel	16 ft.	19 ft.	20 ft.	21 ft.
8 crank	" " " "	16 ft.	19 ft.	20 ft.	21 ft.
6½ crank	Ground covered by pedal	40·84+ inches.			
8 crank	" " "	50·26+ inches.			

Rating wheels by the amount of progression for each turn of the crank (pedal), the following table, compiled by Henry Starkweather, will be found of advantage:

No. teeth in large sprocket.	26 inch wheel.				28 inch wheel.			
	Number of teeth in small sprocket.							
	6	7	8	9	6	7	8	9
18	20 ft.	17 ft.	15 ft.	13 ft.	22 ft.	19 ft.	16 ft.	14 ft.
19	21 ft.	18 ft.	16 ft.	14 ft.	23 ft.	20 ft.	17 ft.	15 ft.
20	22 ft.	19 ft.	17 ft.	15 ft.	24 ft.	21 ft.	18 ft.	16 ft.

The following table shows the gear according to the number of teeth on large and small sprocket wheels:

28 INCH WHEEL.

Sprockets on pedal crank.	Sprockets on rear wheel. 7	8	9
17	68	59½	53
18	72	63	56
19	76	66½	59
20	80	70	62
21	84	73½	65

—New York Evening Post.

HYDRAULIC COPYING PRESS.

THE hydraulic letter copying press here illustrated is, says the Engineer, the latest labor-saving device we have seen for office use. It has an ascending ram

DENISON'S HYDRAULIC PRESS.

carrying the bottom plate, and is arranged to work with water from the ordinary mains—where the pressure is above 30 lb.—to which it is connected by a ½ in. lead pipe. It is fitted with a two-way valve, to which the connections are made in a simple manner. The waste water may be led to a convenient drain, or, as it is not soiled, may be used at a lower level.

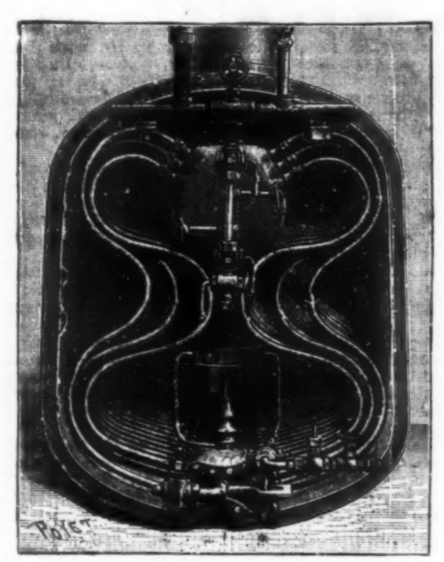
The advantage of the apparatus is, that a boy or girl can apply as much pressure as a man without any fatigue, and the work is much more rapidly done. All that is required is to push the valve handle one way or the other. The ram is packed with a U leather and brass ring, and gives no trouble whatever through leakage. The makers are Messrs. Samuel Denison & Son, of Leeds.

A PETROLEUM-HEATED MULTITUBULAR BOILER.

As well known, the use of petroleum for the heating of steam boilers presents characteristic advantages as compared with the use of coal. This liquid fluid, in fact, possesses a calorific power sensibly greater than that of coal, it lends itself particularly well to the regulation of the consumption while in operation, inspection can be made without difficulty, etc. In a word, we have here a series of considerations that especially recommend petroleum for marine applications, especially when it is a question of pleasure navigation; and at present we in fact have numerous different arrangements designed to permit of the use of this fuel. For example, briquets have been manufactured by mixing petroleum with some other substance; the liquid has been projected in a spray into a glowing furnace; and, again, its vapor has been burned by causing it to be carried along in a brisk current of air or steam. The intervention of such current permits, in fact, of utilizing oil that is but slightly refined and that otherwise would not yield sufficient vapor at the ordinary temperature. It would then be necessary to have recourse to the benzenes, the use of which is costly and at the same time very dangerous. This process of vaporization under the action of an external current is, moreover, the one most frequently employed, and the English Liquid Fuel Company, on its part, has recently applied it under particularly interesting conditions for the heating of the curious type of multitubular boiler that we represent herewith.

The oil of petroleum that serves as a fuel for the vaporization of the water contained in the boiler is sucked up by means of a small air pump (not represented in the figure) and sent under pressure into a vaporizer in which it is converted into gas under the influence of the heat. Thence it passes into a burner, where it is carried along by a strong current of air; and the combustion is thus effected with the production of an elongated flame of great intensity, which envelopes the tubes of the boiler.

The parts in which the combustion is produced—the vaporizer and burner—are both situated in the space left free in the interior of the collection of tubes, so as to assure as perfect a utilization as possible of the heat disengaged. The vaporizer is the horizontal part seen in the center of the figure. It is traversed by a series of tubes that lead the petroleum, and is heated by the flame of the burner situated beneath. The burner itself is a cylinder of small diameter provided



MULTITUBULAR BOILER HEATED WITH PETROLEUM.

with two valves that automatically regulate the entrance of the gas and the draught of air necessary to maintain the combustion.

In the beginning, when it is desired to fire up, it is necessary to heat the vaporizer artificially in order to effect the vaporization of the first oil forced into the tubes, and to this effect a simple spirit lamp filled with asbestos is employed. The oil, traversing the tubes thus heated, vaporizes, the gas disengaged is lighted in contact with the flame of the spirit lamp, and the combustion continues as long as the oil enters.

The first oil is forced from the reservoir to the vaporizer by an air pump worked by hand; but as soon as the motor is in operation it directly actuates an air pump that continues to send the petroleum to the vaporizer. As for the boiler represented, it belongs, as may be seen, to the type of multitubular generators having two reservoirs, one above and the other below. The tubes that connect these reservoirs are of copper and are seamless. They are bent into the form of an S so as to allow of expansion. The whole is established according to a particularly original arrangement that is elaborated in such a way as to prevent useless losses of caloric.

Under such circumstances, owing to the central position given the burner, the ignition is effected with great rapidity. The flames burst forth in a few seconds in enveloping the center of the boiler, and it takes but ten minutes to put the latter under pressure.—La Nature.

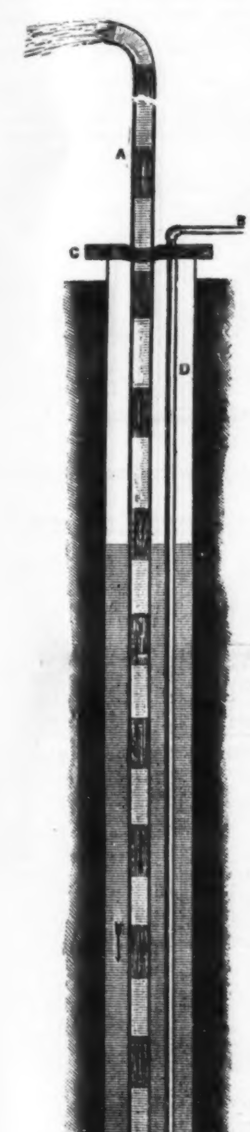
PUMPING WATER BY COMPRESSED AIR.

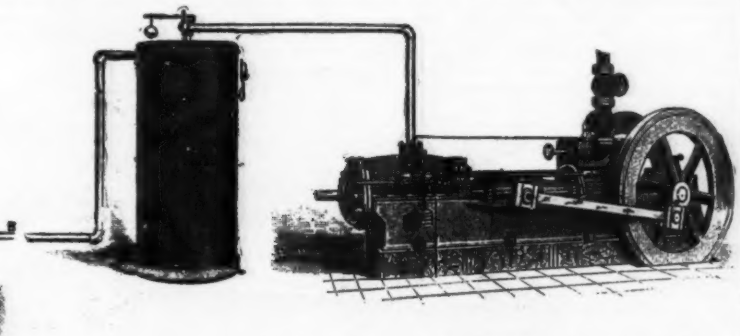
THOSE interested in mining and hydraulics will be glad to have some account of the Pohlé system of raising water from non-flowing wells, mines, etc., which has been introduced into Canada by the Ingersoll-Sergeant Drill Company, of Montreal.

The following description is given by the makers:

The pump proper consists of only two plain open-ended pipes, the larger one with an enlarged end piece constituting the discharge pipe, and the smaller one let into the enlarged end piece of the discharge pipe constitutes the air inlet pipe, through which the compressed air is conveyed to the enlarged end piece to the under side of the water to be raised. No valves, buckets, plungers, rods or other moving parts are used within the pipes or well.

In pumping, compressed air is forced through the air pipe into the enlarged end at the bottom of the water pipe, thence by the inherent expansive force of the compressed air, layers or pistons of air are formed in the water pipe, which lift and discharge the water layers through the upper end of the water discharge pipe. At the beginning of the operation the water





surface outside of the pipe and the water surface inside of the pipe are at the same level; hence the vertical pressures per square inch are equal at the submerged end of the pipe, outside and inside. As air is forced into the lower end of the water pipe, it forms alternate layers with the water, so that the pressure per square inch of the column thus made up of air and water, as it rises inside of the water pipe, is less than the pressure of water per square inch outside of the pipe.

Owing to this difference of pressure, the water flows continually from the outside to within the water pipe by gravity force, and its ascent through the pipe is free from shock, jar or noise of any kind.

These air sections or strata of compressed air form watertight bodies, which, in their ascent in the act of pumping, permit no "slipping" or back flow of water. As each air stratum progresses upward to the spout, it expands on its way in proportion as the overlying weight of water is diminished by its discharge, so that the air section, which may have been say 50 pounds per square inch at first, will be only 1·74 pounds when it underlies a water layer of four feet in length at the spout, until finally this air section, when it lifts up and throws out this four feet of water, is of the same tension as the normal atmosphere; thus proving that the whole of its energy was used in work, and that this pump is a perfect expansion engine.

As the weight of the water outside of the discharge pipe (the head) is one-third greater per square inch than the aggregate water sections within the pipe when in operation, it follows that the energy due to this one-third greater weight is utilized in overcoming the resistance of entry into the pipe, and all the friction within it.

The Pohlé "air lift" pump gives ninety per cent. of efficiency from the air receiver in water pipes of large diameter, and as a rule, above eighty per cent. It retains this efficiency without repairs, or until the pipes rust through, whereas ordinary bucket and plunger pumps gradually lose efficiency from the first stroke they make, and lose it rapidly if the water contains sand or is acid in character. It has been estimated by competent experts, that under favorable conditions and large diameters of water and air pipes, 1,000,000 gallons of water can be raised 100 feet high with one and a half tons of good coal.

The air reservoirs are all strongly made of homogeneous steel, tested and guaranteed at working pressures of 110 pounds; they are provided with the proper openings for inlet and outlet pipes, manhole and head, drain cocks, pressure gage and safety valve.

As the pump has no valves, no standing water remains in the pump column after the operation of pumping; it recedes into the well, and there is none left to freeze in cold weather. The capacity of the pump is unlimited, and with the proper proportions of air to the water, will work efficiently in pipes several feet in diameter. Estimates have been made which indicate that a thirty-inch pipe will deliver 16,660 gallons per minute, equal to 1,000,000 gallons per hour.

As sand, silt, gravel and bowlders in water form no obstacles to interfere with the action of the pump, its adaptability for dredging is suggested as well as its utility for pumping sewage. Experience has proved that by the use of this constant upward flow of water, artesian wells have been freed from their accumulated sedimentary deposits, as well as that lodged in the fissures and crevices of their wall rock, and have been thus made to yield greater quantities of water than they ever did before. For chemical uses, and for the liquids of the arts, there is no superior method than the "Air Lift." It is used successfully for raising sulphuric acid of high specific gravities, and is well adapted for ore leaching works, vinegar works, sugar refineries, dye works, paper pulp works, etc.

As an irrigating pump for raising subterranean water in the arid regions of the West, its field of usefulness is very promising, for with one air compressing plant at a central station, a number of wells, widely separated from each other, may be simultaneously pumped by branches of air-conveying pipes, taken from a main air pipe from the air compressor; for compressed air may be conveyed for miles without material loss of power.

It often happens that a single well does not yield the quantity of water desired, but that a number of wells would give the satisfactory result. By the old fashioned deep well pump, each well would require a separate "steam head," separate sets of rods and the other paraphernalia, which, with the condensation of the steam, when conveyed to the several steam heads, would be very costly in the first outlay, and very wasteful of power in its maintenance, to say nothing of loss of time in repairs. By the Pohlé process, but one air compressing plant is required, and this may be placed in the engine room or the boiler house, directly under the eyes of the engineer, from whence the air may be conveyed to the several wells, all of which may be pumped simultaneously and economically.—Canadian Engineer.

[FROM THE CANADIAN ENGINEER.]

PUMPS AND PUMPING MACHINERY.

By WILLIAM PERRY, Montreal.

THE date from which we commence the history of pumps is the year 200 B. C. Previous to that period there is no mention made of them. Nor has there been discovered any portion that can be judged appertaining to such a machine; the heathen Chinese cannot claim any priority in this special branch, which is peculiar, the more so when we consider their manner of irrigation. A pump is even now a rarity with them.

A pump is not a very intricate machine in itself, and its parts are comparatively few. But its action, or want of it, sometimes makes it seem most mysterious. To those readers who have not considered the question of water dispensation, the remark that pumping machinery stands prominent among the various branches of engineering may seem to allow of discussion. A few instances will very soon give ample proof. How could our coal be obtained and our mines worked, if not for the pumping plant? Our water supply obtained, or our sewage and chemical works carried on? When man enters Nature's storehouse in search of wealth, he finds water ever ready to dispute his supremacy; it may be in a constant stream, varying only with the season; oftentimes vast quantities are stored in crevices of the rocks. Some idea of the quantity of water raised will be given when it is known that often its weight is double and treble that of other material raised, and is frequently 30 per cent. in coal mines.

Rude nations have not possessed the machine, simple as it is, but have always resorted to a more laborious method to obtain water. In the early ages it does not appear to have been known to the Greeks or Romans. Although the pump was invented 200 B. C., it was not until the beginning of the seventeenth century that its true principles were understood; although in 1686 fire engines were built in Holland, and from which, as far as general principles are concerned, no improvements have been made. In 1582, Peter Morris, a Dutchman, contrived a water engine to supply the residents of London from the Thames, and threw water over the steeple of St. Magnus church, at the north end of London Bridge. The introduction of machinery for domestic use commences from May, 1582. The first patent record in England of a pump is patent No. 6, year 1618, by David Ramsay and Thomas Wildgoose. The air pump was invented by Otto de Guericke in 1654. In 1660 Robert Boyle made many improvements in the air pump.

Sir Samuel Morland, Master of Mechanics to King Charles II, in the year 1674 invented and patented the plunger pump, made of cast iron in 1675. He threw water 60 feet high at the rate of 60 barrels per hour, with 8 men, in 1681; the king presented him with a medallion portrait set in diamonds. 1695 is the first notice I have of ship pumps. In 1732 Mr. Demoun invented a pump like a V. In 1741 James Creed secured a patent, No. 579, for making three different machines for making lead pipe for pump use. The first oscillating pump was patented in the year 1750, patent No. 658, by W. Perkins.

The pumps commonly used for raising water from wells may be divided into two classes—lifting pumps and forcing pumps. The lifting pumps may be again subdivided into two varieties, namely, those with a hollow piston and those with a solid or plunger piston.

1. Lifting pumps with a hollow piston, called also atmospheric pumps. This variety, in its simplest form, consists of the following parts:

A cylinder or tube, in which is fixed a valve opening upward, and above which works a piston provided with a valve also opening upward. The part of the cylinder in which the piston works is called the body of the pump, and is the only part which need be bored with any great accuracy. The top of the cylinder may be opened or closed, it matters not which, but somewhere above the level to which the piston ascends there must be an orifice for discharging the water.

The action of the common atmospheric pump is so simple, and is so well known to every school boy, that it will be unnecessary here to dwell upon it. The cylinder is made of various materials, as wood, iron, or copper, and frequently the lower part below the fixed valve is a mere iron pipe furnished with a strainer at its lower extremity. The fixed valve in this kind of pump must be placed at such a level that the depth from it to the surface of the water in the well must never exceed the height of a column of water which will balance the atmospheric pressure or weight of the atmosphere. This weight is measured in the barometer by a column of mercury, which varies in different parts of the world, and at different altitudes, from 28 to 31 inches. Thus, an atmospheric pump at the level of the sea may have its fixed valve several feet higher than a similar pump working on the top of a high mountain. The height at which the mercury stands in a barometer at any given place affords, in fact, a tolerably practical measure of the height to which water will rise in a vacuum when pressed by the external atmosphere. Thus, in theory, where the mercury stands in the tube of a barometer at a height of 30 inches, the sucker or fixed valve of an atmospheric pump may be placed 30 feet above the surface of water in a well. In practice, however, owing to imperfection of materials, fluctuations of level in the water, and other causes, this difference of level is too great, and should not really exceed 25 feet. In shallow wells, therefore, which are not more than about 27 feet in depth, the part of the cylinder or pump above the fixed valve need never exceed the length of the slope or space through which the piston works. In deep wells the ascending part of the cylinder above the body of the pump in which the piston works may be, theoretically, of any height. There are difficulties, however, connected with the valves in the movable piston which render it inconvenient to have the lift in this kind of pump much more than 100 feet. Whatever may be the height of the column of water above the movable piston, it is evident that the absolute weight of this whole column has to be lifted at each stroke of the piston, and for this reason atmospheric pumps, which are worked by hand, have scarcely any of the pump above the piston, as otherwise the weight of water to be lifted at each stroke would be too great for the power to be applied. This practically limits the height to which water can be raised from wells by common atmospheric pumps worked by hand to about 25 feet.

In deep wells, however, when pumps are worked by horse or steam power this objection does not apply, and if the power be sufficient to raise at each stroke the whole column of water above the piston, the length of the cylinder above this piston is only limited by the practical considerations before alluded to in connection with the valves. It should be observed that the common atmospheric pump is seldom or never used in waterworks for the purpose of raising water.

ON CALCULATING THE POWER OF PUMPING ENGINES.

The work performed by steam engines is commonly expressed in what is termed "horse power," that is, an engine is said to be equal to the work performed by a certain number of horses. The standard which has been fixed on to represent the work of one horse is equal to 33,000 pounds raised through a space of one foot high in a minute. This is equivalent to saying that a horse walking at his most effective speed of 2½ miles an hour, or 220 feet per minute, and attached to a weight of 150 pounds freely suspended over a pulley, will raise this weight at the same rate of 220 feet per minute. Using, then, this standard for computing the work of engines—a standard which has been agreed to by the mechanicians of all countries—we obtain a very ready method of determining the horse power required to raise any given quantity of water to any required height. The data required for this purpose

are the quantity to be raised in any given unit of time, and the height to which it is to be raised. The quantity is simply to be reduced to the weight in pounds raised per minute; this weight is to be multiplied by the height in feet, and the product divided by 33,000, in order to find the horse power required to perform the work in question.

A gallon of distilled water, at a temperature of 60° Fahrenheit, weighs exactly 10 lb. avoirdupois, so that by adding a cipher to any quantity expressed in gallons, we obtain its weight in pounds. Suppose now, it be required to find the horse power capable of raising 350 gallons of water per minute to a height of 170 feet. Here we have $350 \times 10 = 3,500$ lb. to be lifted per minute, and $3,500 \times 170 = 595,000$ lb. lifted one foot high per minute, and $\frac{595000}{33000} = 18$ horse power.

When the quantity is expressed in gallons to be raised to a given height in 24 hours, it is necessary to divide this quantity by 1,440, in order to bring it into the quantity per minute, and as $33,000 \times 1,440 = 47,520,000$, if we divide the gallons per day of 24 hours by one-tenth of this, or 4,752,000, we obtain the horse power required to lift it.

The history of the steam pumping engine commences with the atmospheric engine, which is known as the Newcomen type. This is single-acting, the steam raising the piston, and the atmosphere forcing it down where a vacuum is formed by condensing the steam below the piston. This was improved by Watt, who substituted for it, first, his single-acting engine without a crank, and afterward his double-acting engine; but its greatest development has occurred during the present century.

The oldest water works in the United States are supposed to be those at Bethlehem, Pa., which were built in 1754 by Hans Christopher Christiansen, a millwright, a native of Denmark, and being of historic interest, I will enter into the description of it somewhat in detail.

The water was taken from a spring issuing from magnesian limestone, near the banks of the Menogassi Creek, as it was then called. The water was conducted 350 feet through an underground conduit into a cistern, whence it was pumped by a lignum vitæ pump of 5 inches bore, through bored hemlock logs to a height of 70 feet, into a wooden tank in the village square. Trouble was experienced from the bursting of the pipes, and one and one-quarter inch pipes of sheet lead soldered along the edges and buried in a cement of pitch and brick dust and laid in a gutter were tried, without much success.

In 1762 Christiansen, aided by John Arbo and Marshall, constructed larger works. An eighteen foot undershot wheel drove three single-acting force pumps of iron of 4 inches bore and 18 inches stroke. The force main was of gum wood, and the distributing pipes of pitch pine. The latter had to be renewed in 1769. In 1786 lead pipes were substituted for the gum wood force main and for most of the distributing pipes.

The last pitch pine pipes were abandoned in 1791. The reservoir was a wooden tower in the "little square." This was removed in 1803, and a stone tower built on Market Street about 15 feet high, in which was a tank at an elevation of one hundred and twelve feet above the spring.

In 1832 a reservoir was constructed on higher ground, and the water tower abandoned. Also the triple pumps were replaced by one double-acting pump.

In 1868 steam power was used for pumping. In 1874 the wooden conduit from the spring to the pump house was replaced by an 18 inch iron pipe.

Until the year 1800, there were in the United States, including Bethlehem, only eight water works, as follows, in the order of the year of their construction: Providence, R. I., 1772; Salem, Mass., 1796; Geneva, N. Y., and Portsmouth, N. H., 1797; Worcester, Mass., 1798; Morristown, N. J., and Peabody, Mass., 1799.

From 1800 to 1810 there were eleven water works built; from 1810 to 1820, seven; from 1820 to 1830, thirteen; from 1830 to 1840, eighteen; from 1840 to 1850, twenty-five; from 1850 to 1860, fifty-six; from 1860 to 1870, one hundred and three; from 1870 to 1880, three hundred and eighty-one; from 1880 to January 1, at the beginning of 1894, there were over 2,100 water works in the United States, and over 120 in Canada. The proportion of water works in which water is pumped by steam is rapidly increasing, and the subject of pumping engines to do this work is becoming more important every day, but the conditions under which they operate are so varied that it is impossible to go into details in this letter, and I shall, therefore, treat the subject in a general way.

The first requirement of a pumping engine is that it must be able to pump water under the peculiar conditions which it has to work, and to do this continually, successfully, and economically. Its ability to operate day after day, year after year, under the varied requirements of the service, with the least possible expense of repairs and delays, is the most essential fact to be taken into consideration, but, at the same time, it must be capable of easy management, and take care of itself to a great extent after being properly adjusted and started at its work.

The second requirement is economy of steam. Economic use of steam is, of course, important and desirable, but it must not be accomplished at too great expense of repairs and the necessity of continual attention and adjustment on the part of the attendant. The cost of a pumping engine is another important consideration, and is the "stumbling block" of water works companies and committees generally, when a few thousand dollars more of first cost has many times outweighed the above-mentioned qualities, and it has been demonstrated to their sorrow and cost that to own some pumping engines is sufficient to bring great loss and almost ruin, even if the engine had been taken as a gift, on account of the bills for repairs which are contracted, that things may be kept moving.

Pumping engines may be divided into two general classes—crank and fly wheel or rotation, direct-acting or non-rotation, and are made of almost endless variety as to details, the particulars of which I do not care to enter into in this letter. Just where to draw the line that a crank and fly wheel engine should be used and not a direct-acting engine, appears to be debatable ground, and where engineers, like doctors, disagree. It therefore behooves me to handle this part of my letter with great care, and endeavor not to tread on the toes of any pumping engine manufacturer.

The history of the pumping engine construction commences in this country, as in England, with the Cornish engine. This engine gave fine results in the department which it originated—mine pumping. The engine was inordinately large for the work, and made only a casual stroke now and then, as demanded by the flow of water into the mine, the water being delivered at the surface with no force main, and there being no demand for uniform flow.

A glance at the conditions under which it works will explain the otherwise unaccountable fact that a pumping engine without a rival in one place has a failing reputation in another. Its honors were never qualified until it was transplanted from the home of its usefulness to do duty in a service where water was to be discharged through a long main to a great height above the pump, and under the requisition of continuous and uniform delivery. This was the very requirement which, from its nature, the Cornish engine was unfitted to meet. The Cornish engine is in its nature precarious, requiring constant watchfulness on the part of the engineer, and cannot safely be trusted for a minute without this care and supervision. This uncertainty of its action, great first cost, and expensive repairs, has finally led to its abandonment for water works. The crank and fly wheel engine was the first and most obvious alternative. While emulating the economy of the Cornish engine, it was positive in its motion and safer in its character. In the crank and fly wheel engine, steam is cut off at a certain fraction of the stroke, while the remainder is finished by expansion, aided by the momentum of the fly wheel, thus producing great economy in the use of steam at the expense of intricate machinery. These engines operate either vertically or horizontally. They require expensive and massive foundations to absorb the shocks and jars incident to their working, this being especially true of vertical engines, the momentum of the fly wheel in its revolutions increasing to a large extent the accidents that would otherwise be trifling.

The use of duplex direct-acting steam pumping engines in water works dates from about 1854, and it was brought in direct competition with the Cornish, and crank and fly wheel engines. The duplex engine is horizontal in action and usually allows the steam to follow the piston throughout its stroke, thus preserving great simplicity and compactness in working parts.

The foundations required are much lighter and less expensive than that for a crank or fly wheel engine.

The duplex engine is essentially two direct-acting pumps placed side by side, their valve motions being so arranged that the motion of one pump acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon before it can renew its motion. This pause allows all the water valves to seat quietly, and removes everything like harshness of motion, keeping up a uniform delivery, without pulsation or noise. The smoothness of motion and simplicity in steam valve mechanism reduces the liability of accident to a minimum. While it is not claimed that the compounding condensing duplex engine is capable of developing the highest duty, their yearly records are excellent, ranging from 50,000,000 to 65,000,000 duty, and trials have been reported as high as 120,000,000.

It is claimed for these engines that their moderate first cost—engine proper, foundation and building, as well as inexpensive repairs, and small expense of replacing any important part—makes them in a majority of cases the most economical to use.

In conclusion, I trust that I have brought out a few points which may be of interest to your readers on the subject of pumps and pumping machinery. I find in conversation with numbers I come in contact with that pumps and pumping machinery are very poorly understood, even among some of our best mechanics. But they will find, as I do, there is always something to learn, and one man does not know everything about pumps and pumping machinery.

NEW CORLISS ENGINES FOR THE LEICESTER CORPORATION ELECTRICITY WORKS.

NEW compound Corliss engines have been put in, constructed by Hick, Hargreaves & Company, Bolton, which are described as follows in the Engineer, London, with the accompanying illustrations.

The several engines are of the horizontal compound condensing type. They are fitted with Corliss valve gear, and each has its own condenser and air and circulating pump. The larger engines have cylinders 16 in. and 30 in. by 36 in. stroke, and run at 96 revolutions per minute, while the smaller engine has cylinders 11 in. and 20 in. by 24 in. stroke, and runs at 118 revolutions per minute.

Valve Gear.—The valve gear of all the cylinders, except the low pressure cylinder of the small engine, is of the Corliss type, of a design recently patented by the makers to meet the special conditions of electric lighting, and known by them as their "high speed gear." Fig. 1 is from a photograph of the gear of one of the 30 in. low pressure cylinders, and Fig. 3 is a scale drawing of the gear of one of the 16 in. high pressure cylinders. The special features of the gear may, perhaps, be best indicated by a statement of the respects in which it differs from the Corliss gear usually used on mill engines. In almost every Corliss gear hitherto used, the trips have been released by the opening motion of the parts, which implies that the fullest opening of the steam port will only occur on the rare occasion when the engine is working with the longest possible admission, and, as there must be some margin, this is never reached in practice, the port is never fully opened, and at light loads may be a long way from being fully opened when the cut-off takes place. For the same reason, it has hitherto been found necessary to drive the steam and exhaust valves by separate eccentrics, as, if a single eccentric is used, and set to give a suitable motion to the exhaust valves, it is then so far in advance of the crank that the fullest opening of the steam port, and, therefore, the maximum range of the cut-off, occur too early in the stroke. In the gear now illustrated, the release of the trips is effected by a separate supplementary eccentric, which, under the control of the governor, effects the release at any point between zero and the natural closing of the valve. This allows both steam and exhaust valves to be worked by a single eccentric and wrist plate, and causes the steam port to be fully opened at a very early point in the stroke.

The next point is, that the less a Corliss valve is opened the greater is the power needed to close it, because equilibrium has not been so nearly established between the upper and under sides of the valve; but in the ordinary Corliss gear the spring is compressed proportionately with the amount of opening, so that

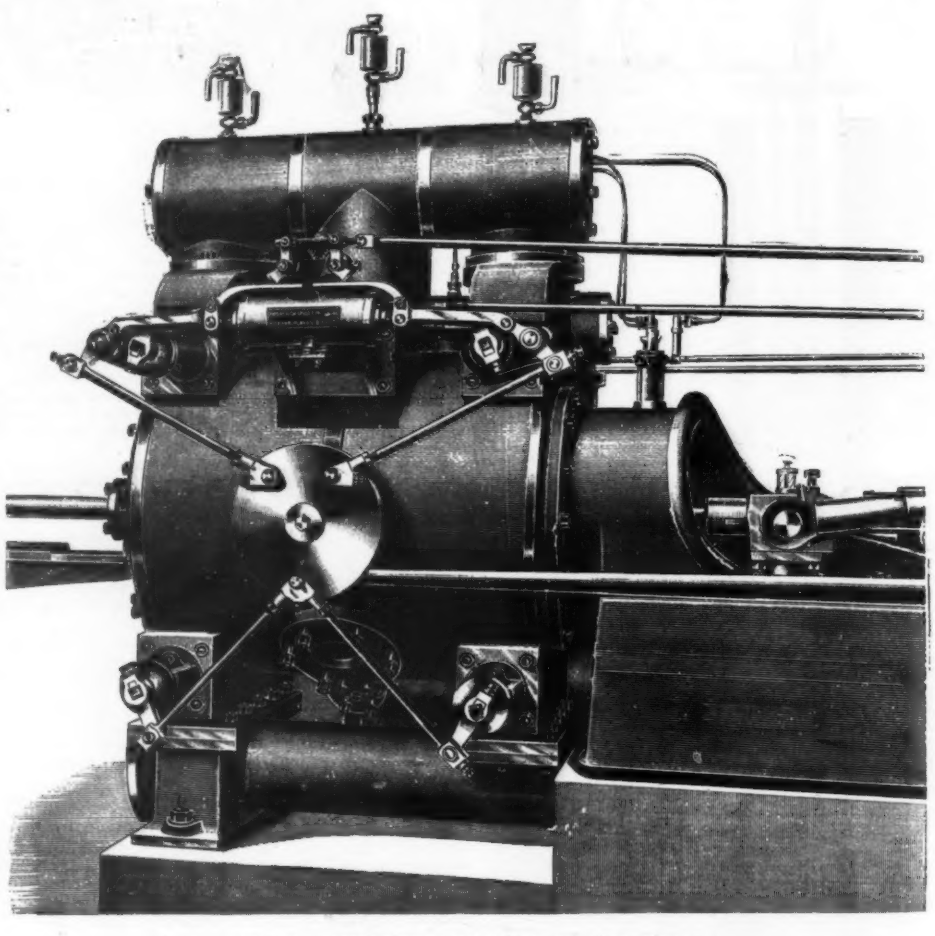


FIG. 1.—IMPROVED CORLISS VALVE GEAR.

the spring gives the greatest thrust when it is least wanted, and vice versa. This is rectified in the new gear by compressing the spring on the return stroke, and carrying it forward on the opening stroke like a loaded and cocked gun, ready to go off with a constant force at any point of the stroke at which the trigger may be released by the supplementary eccentric.

With the foregoing explanation of the special features, it is hoped that the following description of the action of the gear will be readily followed. In Fig. 3 the steam valve on the right-hand side is being opened by the pull of the rod, A^1, through the lever, B^1, and the side rods, C^1, on which is pivoted the detent lever, T^1, and the release of the detent is about to take place through the supplementary eccentric forcing down the detent lever, T^1, by the cam, K^1, when the valve will be closed by the thrust of the spring and cushioned by the dashpot in the usual way. The point of the stroke

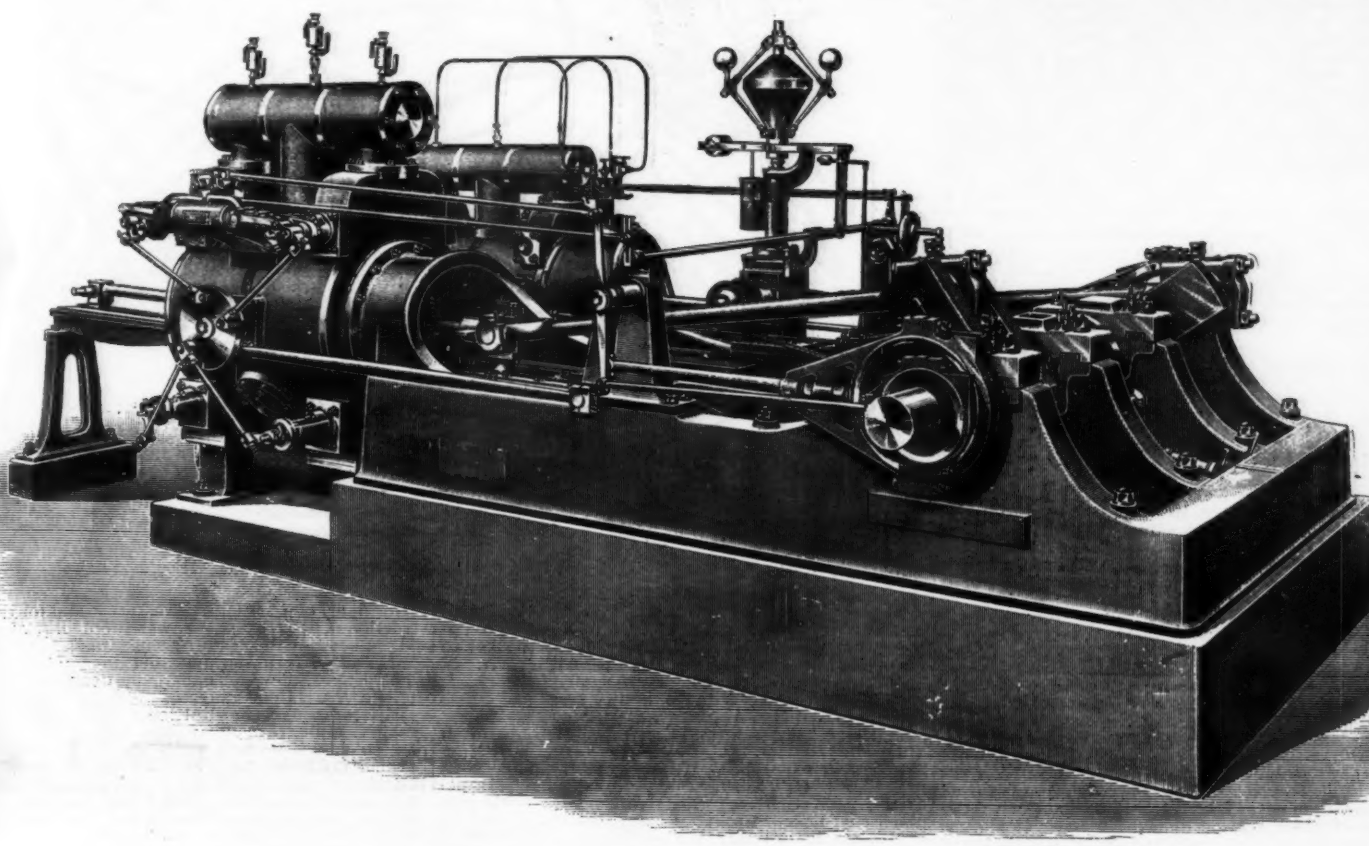


FIG. 2.—GENERAL VIEW OF ENGINE—LOW-PRESSURE SIDE.

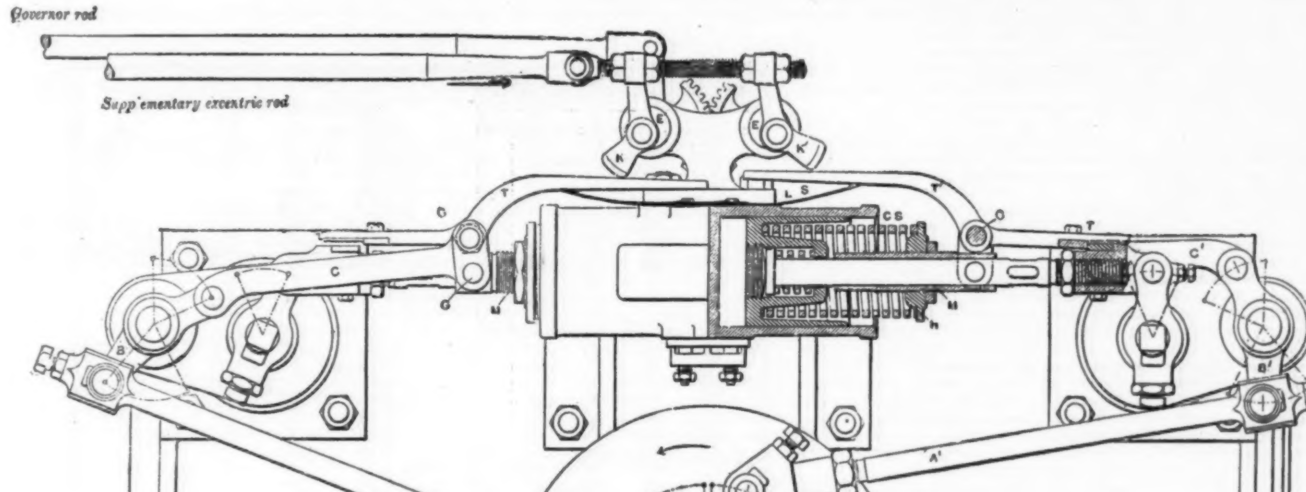


FIG. 3.—HIGH SPEED CORLISS GEAR—HIGH-PRESSURE CYLINDER.

COMPOUND CORLISS ENGINES, LEICESTER CORPORATION ELECTRICITY WORKS.

at which this release will occur is controlled by the governor through the eccentric, E^1, the rotation of which lowers and thereby hastens the action of the cam, K^1, or vice versa. On the left-hand side, the rod, A, has just compressed the spring to an extent adjustable by the nut, H, and lock nut, M, the detent rod, T, will fall into gear as soon as the cam, K, is moved out of the way by the supplementary eccentric, and on the return motion of the wrist plate the valve will be open and come into the position now occupied by the right-hand side. It should be noticed that on the release of the trip or detent only the minimum number of parts have to move rapidly, viz., the valve, its spindle and lever, and the dashpot rod and piston.

THE CHICAGO DRAINAGE CANAL.

DURING the last three years Chicago has spent more than ten million dollars in the construction of a canal which is to turn a portion of the water of the Great Lakes along an old glacial outlet into the Mississippi Valley, and carry the sewage with it so diluted that it will not be a menace to the health of the Illinois Valley through which it is to flow. Ten million more dollars will have to be spent before the canal is in active operation; but the work is prosecuted with such energy that its completion is looked for within the next two years. This is not to be a canal with locks to regulate the flow of water, but an open channel 160 feet wide at the bottom, and 18 feet deep, with plans for deepening it still more in the future. When first opened it is to discharge 10,000 cubic feet of water per second, which is about five per cent. of the amount now flowing through Niagara River. When the population of the city shall exceed 3,000,000, the quantity of the discharge is to be increased in proportion to the excess. The amount of the original discharge is so great that the engineers estimate that it will raise the low water mark of the Mississippi one foot at St. Louis.

The accomplishing of such an enormous enterprise is rendered possible by the peculiar physical geography of the Great Lakes. Lakes Michigan and Huron are practically on the same water level, about 580 feet above the sea, while Lake Erie is only eight feet lower. Lake Superior is in an independent basin 20 feet higher. The basin of the lower three of these lakes is so delicately poised that only four feet of rock and two of gravel at Chicago prevent them from spilling over into the Mississippi Valley at high water. The rock bottom of the Niagara, where it leaves Lake Erie, is only 30 feet lower than the rock shelf which forms the barrier west of Chicago. An elevation of 50 feet at Buffalo, or a depression of the same amount at Chicago, would reverse the drainage and make the four upper lakes tributary to the Mississippi. This plan for the disposal of Chicago's sewage has been devised by the city and the State without formal consultation with the other parties whose interests may be affected by it. It seems to be assumed that, since the canal is wholly within the territory of Illinois, it is not necessary to consider the other interests involved. But the cities along the lower lakes are just beginning to be aroused to a consideration of the possible effect of this scheme upon the level of the lakes, and upon the depth of the water in their harbors and in the channels which have been deepened at great expense to facilitate commerce to their ports. The Cleveland Chamber of Commerce has just petitioned the Secretary of War to investigate the matter at once.

The total drainage area of the four upper lakes is 250,000 square miles, with a rainfall of about 31 inches. If we reckon that from 35 to 40 per cent. of this is now discharged through Niagara River (which is a liberal estimate), it would make the amount to be about 200,000 cubic feet per second. Major Ruffner estimated that the diversion of 5 per cent. of the water flowing into Lake Erie will probably reduce its level nine inches. The Chicago engineers, basing their calculations on earlier and less perfect data, have been

reckoning on a lowering of the level of from three to five inches only. But in view of the shallowness of all the harbors on Lake Erie, and of the fact that the United States has but just completed its work of deepening the navigable channel two feet at a cost $2,000,000, even the lesser estimate is by no means an insignificant item. Furthermore, the engineers in charge freely talk of diverting 15 or 20 per cent. of the water of the Great Lakes into the Illinois, so as to give such continuous volume to both that stream and the Mississippi as to make both navigable at all times to the largest steamers. If this canal shall be adopted by the United States as a part of its system of internal navigation, it seems evident that the general government will be called upon to protect the other interests involved from injury. If it is not adopted as a national waterway, it will be an interesting question whether the cost of repairing damages can be assessed upon the city of Chicago, which is to receive the direct benefit from this diversion of a public waterway.

It must be confessed that the boldness of the Chicago engineers, and the promptness with which the city is proceeding to carry out their plans, are scarcely less than sublime. In olden times this project of Chicago might easily have become the occasion of a war between the East and the West, or between Canada and the United States. But there will be ample time to prepare for the remedy of incidental evils before the canal shall become a fixed fact; for so vast are the stores of water in the Great Lakes that four or five years would elapse before the full effect of such a diversion as is contemplated would be felt upon the lake level. It certainly is remarkable that the solution of a most difficult problem in disposing of a city's sewage should render financially practicable one of the boldest schemes for the improvement of internal navigation which have ever been entertained by engineers anywhere in the world.—Eve. Post, N. Y.

THE TUNNEL UNDER THE THAMES AT BLACKWALL*.

By Maurice Fitzmaurice, M. Inst. C.E.

The construction of tunnels is a subject which has been dealt with on several occasions in papers read before the British Association.

In 1887 the late Mr. T. A. Walker read a paper on the Severn Tunnel and in 1892 Mr. George F. Deacon read a paper on the Vyrnwy Aqueduct Tunnel under the Mersey. Mr. Deacon had just finished the construction of this tunnel under the Mersey by means of a shield and compressed air, and had an interesting tale to tell of the great difficulties met with in this work, and how after nearly four years of struggling and anxiety it was accomplished successfully.

Since the completion of the City and South London Railway in 1890, tunneling by means of a shield and compressed air has been carried on to a large extent in this country. Tunnels have been constructed by this method under the Clyde just below Glasgow, and also at several points in Glasgow in connection with the Glasgow District Subway. A tunnel is also being constructed in Edinburgh by the same means.

In all these tunnels compressed air has been used almost continuously in conjunction with shields, as the amount of water met with has been large, and it has been necessary in some cases to avoid all subsidence of the ground above as much as possible.

The tunnel under the Thames at Blackwall, which is being built for the London County Council under the direction of their Chief Engineer, Mr. A. R. Binnie, has been under construction for more than two years; and although the greatest difficulties have probably yet to come, still the author hopes that an account of the inception of the undertaking, and a description of the present state of the works and the difficulties met with up to date, may not be without interest.

Before dealing with the Blackwall Tunnel, the author proposes to make a few short remarks on previous tunnels constructed by one or both of the methods under consideration.

In the paper by Mr. Deacon already mentioned, reference was made very shortly to the old Thames Tunnel between Wapping and Rotherhithe, constructed by Brunel between the years 1825 and 1842, which was the first tunnel constructed by means of a shield. It is unnecessary, therefore, to refer here to the difficulties encountered in the construction of this work, and to the energy and courage with which they were met by Brunel.

The idea of using a shield for tunneling had occurred to Brunel many years before he began this tunnel, and he took out a patent for the construction of tunnels by this means as early as 1818. In the specification of this patent, Brunel states: "The great desideratum, therefore, consists in finding efficacious means of opening the ground in such a manner that no more earth shall be displaced than is to be filled up by the shell or body of the tunnel. In the formation of a drift under the bed of a river, too much attention cannot be paid to the mode of securing the excavation against the breakdown of the earth. It is on that account that I propose to resort to the use of a casing or a cell, intended to be forced forward before the timbering which is generally applied to secure the work."

He then described a shield, circular in section, and composed of different cells, any one of which could be shoved forward a short distance by itself, independently of the others, and having the space left between the shield and the completed portion of the tunnel guarded by plates lapping on to both. He then states: "Each cell is to be moved or forced forward by any mechanical aid suitable to the purpose, but I give the preference to hydraulic jacks." As regards the tunnel, he says: "The body or shell of the tunnel may be made of brick or masonry, but I prefer to make it of cast iron, which I propose to line afterward with brickwork or masonry."

Though the shield used for the construction of Brunel's tunnel was not the same as described in the specification, the former being rectangular and shoved forward by means of screw jacks butting on the completed portion of the tunnel, which was constructed of brickwork, still we have here prominently brought forward by Brunel the idea of a tunnel made of cast iron lined with brickwork, and constructed by means of a shield which had a tail lapping over the completed portion of the tunnel, and shoved forward in small sections by means of hydraulic jacks.

In 1830 Cochrane took out a patent for using compressed air to keep back the water met with in driving shafts or tunnels, but it does not appear that any shaft was sunk by this method before 1839, when a shaft was sunk at Chalonnes, in France, through a quicksand, and compressed air was not used in any tunnel before 1872 or 1873.

The use of compressed air in conjunction with a shield, and the construction of the tunnel itself with cast iron rings, although the latter may not be so important in some cases, may be considered the key to tunneling in loose or soft ground filled with water.

The question of settlement, especially in towns, is an important one. When pumping has to be done, the water is naturally drawn down in the adjacent strata, and, in addition, quantities of sand often come with the water, and settlement occurs from the first or from both of these causes. When compressed air is used, no pumping, of course, is necessary, and therefore there can be no settlement under that head. Probably the most fruitful cause of settlement in ordinary tunnels is caused by the fact that more ground is taken out than the tunnel actually fills, and although the utmost care is taken in supporting the ground and packing all cavities, a certain amount of settlement invariably occurs. With a shield the excavation is reduced to almost the net section of the tunnel, and therefore no settlement can take place to any appreciable extent. As regards safety in working, it is evident that when only the face of the excavation is open, and that perhaps only in small areas, and the water is kept back by compressed air, that the maximum of safety is assured. The great advantages of constructing the tunnel of cast iron segments are that it is much quicker and convenient to build than brickwork, and that, unlike this latter, it has its full strength as soon as it is built; and this is a very important matter in soft ground, which exerts a heavy pressure on the tunnel.

Although tunneling by these methods has the above advantages, there are still many difficulties to be surmounted, a fact which is well evidenced in Mr. Deacon's account of the Mersey Tunnel. In loose ground great precautions have to be taken against the compressed air blowing out at the face, particularly in tunnels of large section, where the water pressure is much greater at the bottom than at the top, and the support of the face is always a matter of difficulty.

In 1869 the Tower Subway was constructed by Mr. Peter Barlow and Mr. J. H. Greathead. It is interesting as being the first tunnel in which a shield shoved forward as one structure was used, and for the construction of which cast iron was adopted. The external diameter of the cast iron rings was 7 ft. 1¾ in.; the tunnel was driven through the London clay for its whole length, no water had to be dealt with, and no difficulties were encountered.

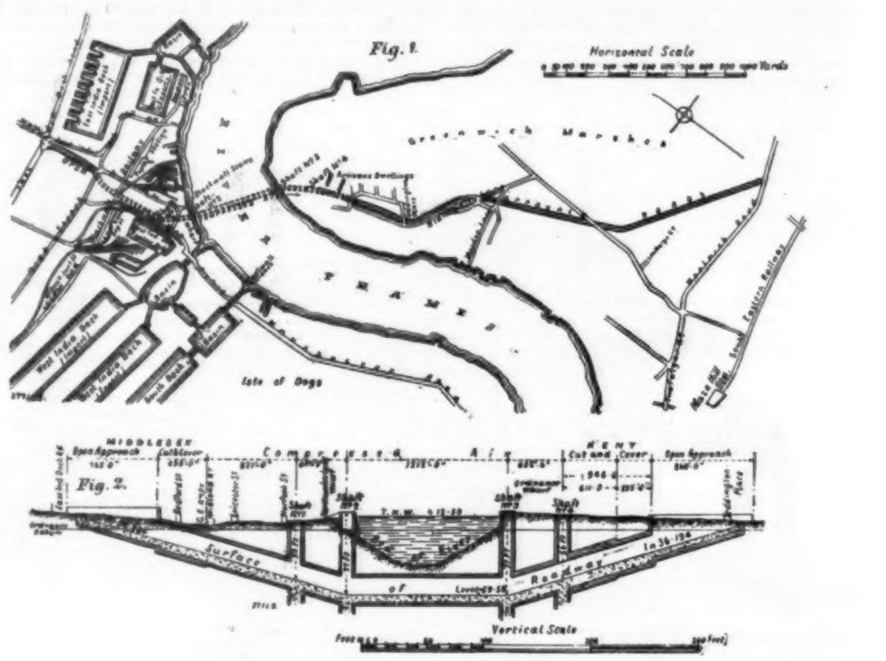
In 1870 an experimental length of tunnel was constructed under Broadway, New York City, by means of a shield known as Beach's shield,* for the purpose of demonstrating the practicability of constructing tunnels by means of a shield without any settlement of the superincumbent ground, and therefore without cracking any adjacent buildings. This experimental length of tunnel was 8 ft. in diameter.

A tunnel of the same diameter was constructed by means of a similar shield in the following year under the streets of the city of Cincinnati, for drainage purposes.

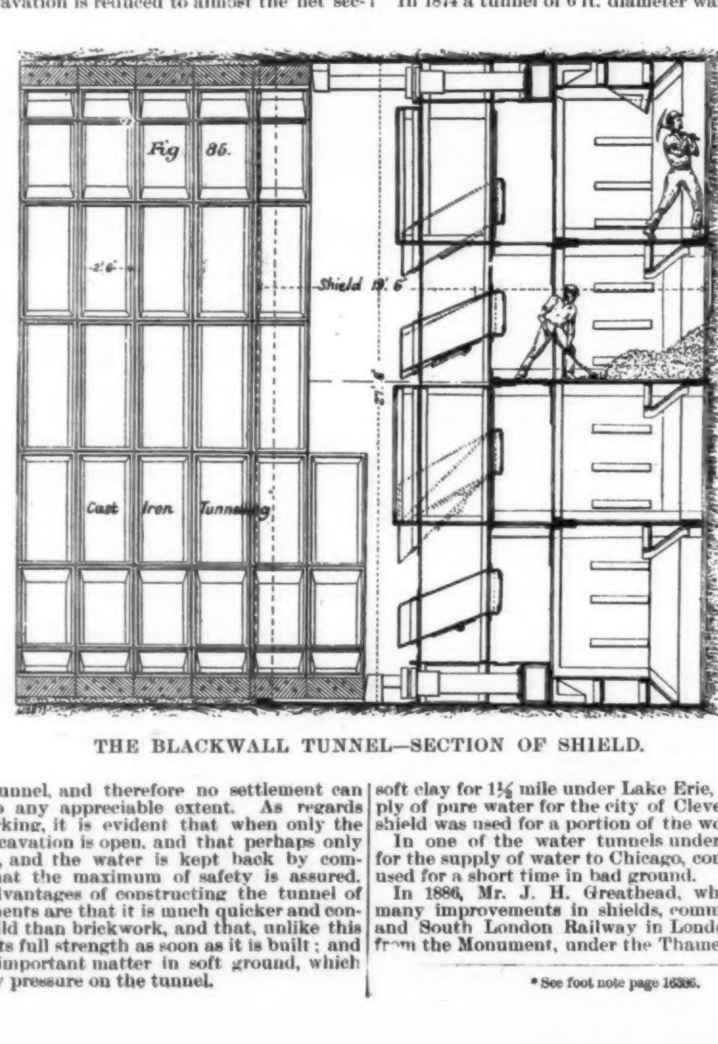
In 1874 a tunnel of 6 ft. diameter was driven through soft clay for 1¼ mile under Lake Erie, to obtain a supply of pure water for the city of Cleveland, O., and a shield was used for a portion of the work.

In one of the water tunnels under Lake Michigan for the supply of water to Chicago, compressed air was used for a short time in bad ground.

In 1886, Mr. J. H. Greathead, who has patented many improvements in shields, commenced the City and South London Railway in London,* which runs from the Monument, under the Thames, to Stockwell,



THE BLACKWALL TUNNEL, LONDON.



THE BLACKWALL TUNNEL—SECTION OF SHIELD.

* Read before the British Association, Oxford, 1894.

* See foot note page 16386.

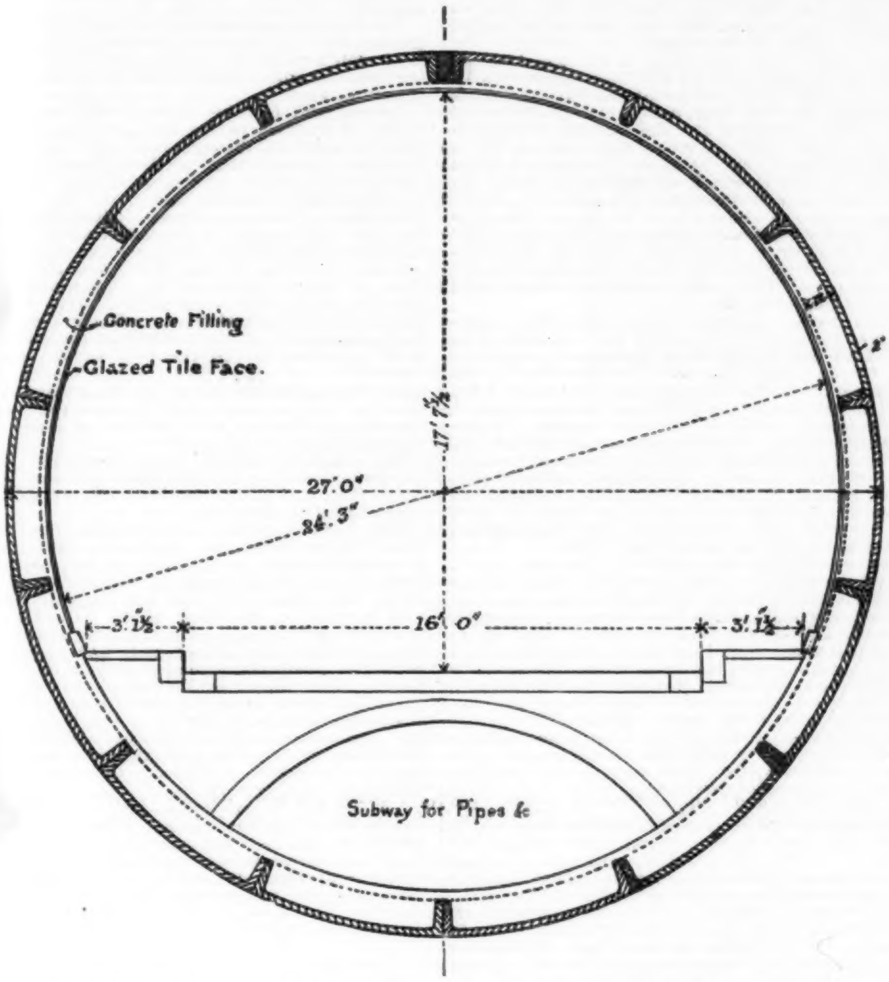
a length of about three miles. The railway consists of two separate tunnels lined with cast iron segments, 11 ft. 3 in. external diameter, and all constructed by means of shields. With the exception of three lengths, one of which was 750 ft. long, where pockets or veins of gravel or sand were met with, and which necessitated the use of compressed air, and which was the first occasion in which compressed air was used in con junction with a shield, the tunnels were driven through London clay, where no compressed air was necessary.

The first tunnel on a large scale completed by means of a shield and compressed air was the St. Clair Tunnel,* constructed under the St. Clair River, which runs from Lake Huron to Lake Erie. The ground through which the tunnel was constructed consisted for the most part of soft clay, with occasional pockets of gravel and sand.

The highest air pressure used was about 32 pounds per square inch above the atmospheric pressure. The external diameter of the tunnel, which was constructed of cast iron, was 21 ft. A shield was started on each side of the river, working toward the center, and the maximum progress made by one shield during a month was 382 ft., equivalent to an average progress of 12 ft. during a day of 24 hours. The work was begun in 1888 and finished in 1890.

Previous to the construction of the City and South London and the St. Clair Tunnels, compressed air had been used in the tunnel under the Hudson, at New York. A shield was not used here in the first instance, but was adopted later on.* This tunnel is made through extremely soft clay, and is constructed with iron segments of 19 ft. 8 in. external diameter. This work, which was begun in 1871, has now been suspended since 1891, on account of financial difficulties, although the greater portion of it is completed.

* See foot note page 16386.



THE BLACKWALL TUNNEL—CROSS SECTION OF IRON LINED TUNNEL.

The tunnels constructed, and being constructed, in Glasgow and Edinburgh, have already been referred to.*

In 1877 the late Metropolitan Board of Works obtained powers to purchase and free the various toll bridges over the Thames, and this was carried out at a cost of £1,500,000.

The ratepayers east of London Bridge, who had paid their share of this sum, naturally agitated for increased facilities for crossing the Thames between London Bridge and Woolwich, a distance of about nine miles, in which there was at that time no free river crossing.

The outcome of this agitation has been the establishment of a free ferry at Woolwich, the building of the Tower Bridge just opened, and the construction of the Blackwall Tunnel.

The Metropolitan Board of Works brought several schemes for crossing the Thames before Parliament between the years 1879 and 1887, and finally, in the latter year, obtained powers for the construction of a tunnel or tunnels at Blackwall.

Tenders were then invited for the construction of a tunnel for foot passengers of 15 ft. internal diameter, and the tender of Messrs. Pearson & Son, amounting to £318,840, was accepted by the Board. On the Metropolitan Board of Works being succeeded by the London County Council, the latter refused to confirm the contract with Messrs. Pearson, principally for the reason that they considered it would be better to make a tunnel of a larger diameter than 15 ft. in the first instance.

In November, 1889, Mr. John Wolfe Barry was instructed to report to the Council on the possibility of the construction of a tunnel of a larger diameter, and he reported that it was possible to construct a tunnel at Blackwall large enough to take both vehicular and foot traffic.

In 1890 Sir Benjamin Baker was instructed by the Council to inspect the Hudson and St. Clair Tunnels, then in progress in America, and to advise them as to the best way of proceeding at Blackwall. The result of this examination was that he reported to the Council that there would be no serious difficulty in constructing at Blackwall a tunnel large enough to convey two lines of vehicular traffic.

In December, 1890, Mr. A. R. Binnie, the Engineer-in-Chief to the Council, after consultation with Sir Benjamin Baker and Mr. J. H. Greathead, reported that a tunnel of 27 ft. external diameter was the best size to adopt, and that the bottom of the tunnel should be at such a level that the maximum air pressure necessary for its construction should not exceed 35 pounds per square inch above the atmospheric pressure.

The contract drawings were then got out under Mr. Binnie's directions, in consultation with Sir Benjamin Baker and Mr. J. H. Greathead, for a tunnel of this diameter, and tenders invited for its construction. The tender of Messrs. Pearson & Son, amounting to £871,000, was accepted, and the work was commenced early in 1892; and Mr. D. Hay and the author were appointed by the Council as Resident Engineers on the work under Mr. A. R. Binnie, and Mr. E. W. Moir took charge of the works on behalf of the contractors.

The Blackwall Tunnel is much larger than any tunnel yet constructed by the methods adopted. The outside diameter of the St. Clair Tunnel, which is the largest one at present, is 21 ft., while that at Blackwall is 27 ft. in external diameter. The following are some of the leading dimensions:

Length from entrance to entrance.....6,200 ft.

This total length is divided as follows:

Open approaches, flanked by retaining walls...	1,735 ft.
Cut and cover portion, built of brick and concrete...	1,382 "
Cast-iron lined portion...	3,083 "
The width of roadway is...	16 "
And the width of each footpath....3 ft. 1½ in.	

The tunnel is level under the river, and the gradient on the north side is 1 in 34, and on the south side 1 in 36.

There are four vertical shafts, two on each side of the river. The depths of these shafts below ground level are:

No. 1 Shaft...	75 ft.
" 2 " ...	98 "
" 3 " ...	98 "
" 4 " ...	76 "

Each shaft is a wrought iron caisson of 58 ft. external diameter at the bottom and 48 ft. internal diameter throughout, and lined inside with brickwork. The batter of the outside is only that due to the lap of the plates, each strake being vertical, and is equivalent to an average batter of 1 in 100.

Each caisson consists of two skins varying in thickness from ⅜ in. to $\frac{9}{16}$ in., about 5 ft. apart, and braced together; the space between being filled with concrete. Two circular holes, 29 ft. 4 in. in diameter, are left in each caisson to give way for the tunnel through the shaft, and these holes are temporarily plugged while the caisson is being sunk. About 8 ft. from the bottom the inner skin is bent outward to meet the outer skin at the bottom to form a cutting edge, which is strengthened by heavy diaphragms, and a circular steel belt 1 in. thick.

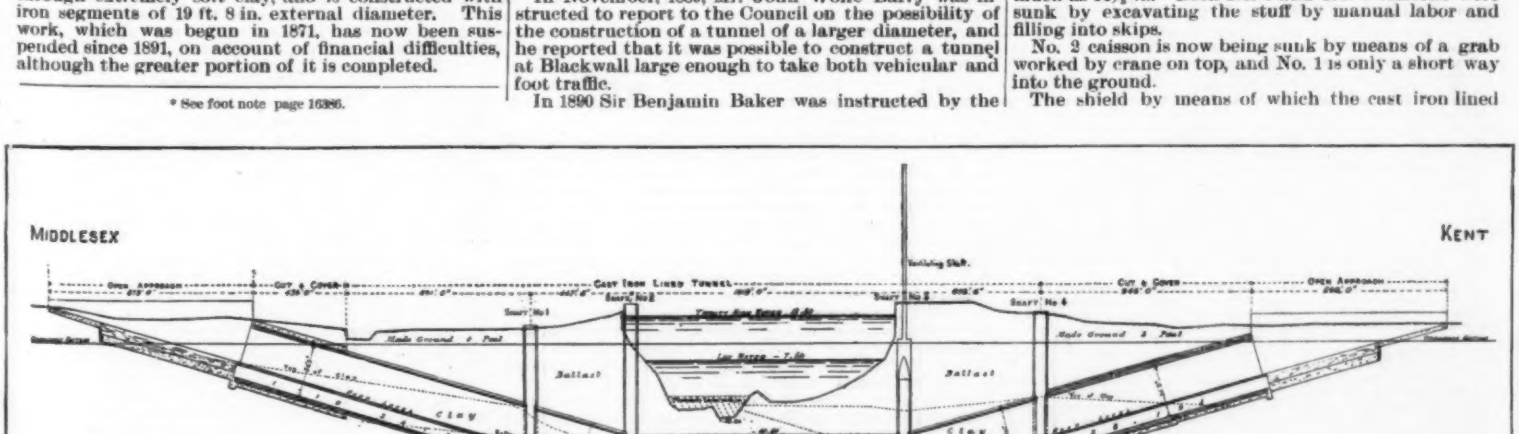
Provision is made for fixing an airtight floor in each caisson above the tunnel level, so that air pressure can be used in sinking it if necessary, and also to allow of the tunnel being constructed under compressed air while entering the shaft.

After the caisson has been sunk to its full depth, concrete is filled into the bottom up to the level of the invert of the tunnel, a depth of about 13 ft., but previous to this a watertight wrought iron floor is fixed below the concrete to prevent any water finding its way between the side of the caisson and the concrete, or through the latter.

No. 4 caisson, which was the first one sunk, was got down without much difficulty, but a great deal of trouble was, however, experienced with No. 3. When it had been sunk 80 ft. it came to a bed of quicksand 8 ft. deep, which was got through with the greatest difficulty, and at one time it was feared that compressed air would have to be adopted. Eventually, by loading it with 1,500 tons of iron and bricks, which, with the weight of the caisson itself and the concrete between the skins, made a total weight of nearly 5,000 tons, and by the aid of a large pumping power, it was sunk to its final level, and was only 9 in. out of level, although during process of sinking it had been as much as 14½ in. Both No. 3 and No. 4 caissons were sunk by excavating the stuff by manual labor and filling into skips.

No. 2 caisson is now being sunk by means of a grab worked by crane on top, and No. 1 is only a short way into the ground.

The shield by means of which the cast iron lined



THE BLACKWALL TUNNEL, LONDON—LONGITUDINAL SECTION.

portion of the tunnel is being constructed is shown in Plate II. It is 19 ft. 6 in. long over all. The outside shell consists of four ⅝ in. steel plates. There are two vertical plate diaphragms at right angles to the axis of the shield, and dividing it into two parts. These diaphragms being made airtight, a greater air pressure can be maintained at the working face in front of the shield than in the back portion of the tunnel. The space between the two diaphragms forms air locks for going from one pressure to the other, and the diaphragms are provided with rubber-faced doors for ingress and egress. The material shoots passing through the diaphragm space are also provided with doors at each end, and act as air locks.

The portion of the shield back of the first diaphragm, known as the "tail" of the shield, consists simply of the outer shell before referred to; but forward of this diaphragm there is also an inner skin connected stiffly to the outer skin by circular girders and in other ways, and both joining together at the cutting edge.

The working face is divided up by three horizontal and three vertical stiffening plate diaphragms in the line of the axis of the shield, into four floors and twelve working compartments.

At 6 ft. 7 in. back from the cutting edge there is a vertical iron screen, coming down from the roof of each compartment, and back of this screen, between it and the air lock diaphragm, is what may be called a safety chamber; should there be a sudden rush of material and water—owing to the compressed air suddenly blowing out, or from other causes—the men retreat behind this screen, and as its lower edge is some distance below the top of the compartment, they are enabled to stand there with their heads above water. Arrangements are made at the face in each compartment for using horizontal iron poling boards when in ballast, running in guides at each side, and shoved forward by means of jacks. It has not been necessary up to the present to use these. Around the circumference of the back of the shield are arranged 28 hydraulic rams, which shove forward the shield by pressing against the cast iron lining already erected. Each ram is 8 in. in diameter, and with a water pressure of 2 tons to the inch exerts a pressure of about 100 tons, making no allowance for the friction in the jack, which gives, therefore, a pressure of 2,800 tons on the back of the shield. A water pressure of 2¾ tons to the inch has been used at times. These rams also help to guide the shield. If it is required to be driven a little bit to one side, the rams on that side are shut off, and those on the other side turned on, and similar in guiding it for level. Some difficulty is occasionally encountered in steering it in this way, as if a large number of rams are shut off there may not be sufficient rams on to shove the shield forward, but in the 600 ft. of tunnel driven to date the lining is not more than 2 in. out of straight, and that only at one point.*

* The tunneling shield above described in its general principles of construction and operation, is known as the Beach Hydraulic Shield. It is now generally used by engineers in all parts of the world, where earth tunneling work, of considerable depth, is required. The machine was designed in 1865, by Mr. Alfred E. Beach, of the Scientific American, New York, and used by him in 1869, for the purpose of excavating under the streets of New York, with a view to an underground railway. At that early period the need of rapid city transit for passengers was strongly felt, but there was great opposition on the part of property owners along the line of the proposed railway, through fear that the buildings would be injured if a tunnel were carried on a lower level than the foundations; added to which would be serious loss of business by the closing and tearing up of the streets during the construction of the work. Mr. Beach determined to show the fallacy of both of these objections by excavating a short piece of tunnel under the most crowded part of Broadway, at a lower depth than the adjacent buildings, and without interrupting business or traffic. He accordingly constructed the hydraulic shield or underground boring machine, which he set to work, and with it constructed a tunnel extending under Broadway from Warren Street to Park Place, large enough to receive a small street railway car, the length of the tunnel being between three hundred and four hundred feet. This tunnel was 9 ft. 4 in. in exterior diameter. It was started at the head of Warren Street, from which it turned underground on a radius of about 50 ft. into Broadway. The curved portion of the tunnel was walled with cast iron plates, put up in segments and united by means of screw bolts; the straight portion was walled with brick masonry. The object of the shield was to protect the workmen while excavating the earth and building the tunnel.

The shield consists of a strong cylinder somewhat resembling a huge barrel with both ends removed. The front end of the cylinder is sharpened, so as to have a cutting edge to enter the earth. The rear end of the cylinder, for a length or two feet or so, is made quite thin, and is called the hood. Arranged around the main walls of the cylinder and longitudinally therewith are a series of hydraulic jacks, all operated from a common pump, each jack having cocks, whereby it may be cut off from the pump whenever desired.

Within the shield are vertical and horizontal braces and shelves. When at work, the iron plates or the masonry, of which the tunnel is composed, are first built up within the thin hood of the shield, the hydraulic jacks are then made to press against the end of the tunnel plates or masonry, which has the effect to push the shield ahead into the earth for a distance equal to the length of the pistons of the jacks, say two feet, or not quite the length of the hood, and, as the shield advances, men employed in the front of the shield dig out and carry back the earth through the shield. By the advance of the shield, the hood within which the iron or masonry tunnel is built is drawn partly off from and ahead of the constructed tunnel, thus leaving the hood empty. The pistons of the hydraulic jacks are then shoved back into their cylinders, and a new section of tunnel is built up within the hood as before described. The shield is then pushed ahead, and so on. The extreme end of the tunnel is always within and covered and protected by the hood. In this manner the earth is rapidly excavated or bored out, and the tunnel built, without disturbing the surface of the ground.

The floor of the Broadway tunnel above mentioned was 21½ feet below the pavement. It was carried under sewers and beneath the Croton water mains. The work was executed while the street was thronged with omnibuses and heavy teams, and few persons, except those directly interested, had any knowledge that a tunnel was in progress until after it was completed. It was then opened to the public, and many thousands of people enjoyed the privilege of riding in the car, which was worked back and forth in the tunnel by the pneumatic or air pressure system.

By means of the system of hydraulic jacks capable of either combined or separate action, Mr. Beach was enabled to govern the direction of his tunneling shield with the utmost precision, making it to ascend or descend in the earth, according to grade required, or travel on a curve of any desired radius. The first machine attracted much attention on the part of engineers. Full accounts of the working of the device were printed in the New York daily papers of 1869. It was illustrated and described in the Scientific American of March 5, 1870, also in the Manufacturer and Builder in 1872, and in various other publications.

Since the construction of the Broadway tunnel the Beach Hydraulic Shield has been employed on a number of important engineering works, with much success, and it is now generally recognized as an important adjunct in the execution of various classes of underground tunnels.

When the promoters of the electric City and South London Railway were before Parliament in 1882 for the purpose of obtaining authority to build their tunnels, they met with opposition from property owners along the line and a searching inquiry was made into the particulars of the intended mode of building. Among the witnesses for the promoters was Sir Benjamin Baker, who gave as one of his reasons for believing practicable their proposed plan of tunneling by means of hydraulic shields, that it had been successfully operated in New York.

Greathead made use of the Beach Hydraulic Shields in building (1886-9) the City and South London tunnels. He is also using them on the tunnels of the Waterloo and City Electrical Underground Railway now in process of construction. The Beach Hydraulic Shields were also used in the construction of the great railway tunnel, 21 ft. diameter, under the St. Clair River (1890), between Port Huron, Mich., and Sarnia, Canada, also in the Hudson River tunnel, New York, also the new East River gas tunnel, under the East River, 71st Street, New York. For the three tunnels under the Clyde at Glasgow and the Edinburgh tunnels, both lately completed, the Beach machines were employed. The most remarkable work on which the Beach Hydraulic Shields have been used is the Blackwall tunnel, which is 27 ft. diameter.—Ed. Scien. Amer. Sup.

When the shield has been shoved forward to allow the erection of one ring of the cast iron lining, the tail of the shield still laps on to and outside the previous ring erected, and the new ring is then erected also inside the tail of the shield. At the back of the shield are fixed two hydraulic erectors, which take up each segment of the cast iron rings and put it into place, and hold it there until bolted to the adjacent rings. Each segment weighs about one ton.

The shield was erected on top, and had to be got down to the bottom of No. 4 caisson, to start the tunnel from there. Its total weight was about 230 tons. A tank or dock was cut out in the ground on top, sufficiently deep to float the shield, and it was built in this. When finished its ends were timbered up, and the dock was connected with the caisson by temporarily taking away a portion of the side of the latter. Both were then filled with water, and the shield was floated into the caisson, and then lowered to the bottom by pumping out the water.

Each ring of cast iron lining is 2 ft. 6 in. long, and consists of 14 segments and a key; each segment, as stated above, weighs 1 ton, and the metal is 2 in. in thickness. The flanges are 12 in. deep, and vary in thickness from 3 in. to 2 in. All joints are planed, both circumferential and longitudinal. A recess, 2 in. deep, is left on the inside of each joint, to allow of calking with rust cement. As before stated, the tail of the shield laps outside the rings, so that when it is shoved forward it leaves a space of about 4 in. at the back of the rings. This space is filled with grout, driven in through a screwed hole, left in each segment for the purpose, by high pressure air, used in one of Greathead's patent grouting pans. This makes everything at the back of the rings absolutely solid.

When driving was first started from No. 4 caisson the face for about 2 ft. deep at top consisted of ballast which had already been drained, to a certain extent, by the pumping in the "cut and cover" portion of the work. At the bottom there was about 1 ft. of sand, and the remainder of the face was hard clay. It was therefore settled to go some distance without using air pressure. As it was known the tunnel would run out of the ballast in a short distance, it was decided to drive a small top heading in front of the shield, instead of fixing up the poling boards already referred to, and the work was done very well in this way, no other timber being used. The first permanent ring of tunnel was put in on June 9, 1893.

As the shield was running down a gradient of 1 in 36, and the beds of clay and sand were nearly horizontal, the ballast in the top gradually disappeared, and the depth of sand in the bottom increased. Even after there was some clay between the top of the shield and the ballast there was a good deal of difficulty experienced in dealing with the latter, as the movement forward of the shield seemed to break the thin crown of clay, and great quantities of water found their way into the tunnel between the tail of the shield and the cast iron lining. It was not, however, anything in excess of what could be dealt with by the pumps.

By the first week in August, two months after driving had been started, 50 rings had been erected, being equivalent to a length of 125 ft. At this point a slight deformation of the cutting edge was noticed at the left hand side in the bottom chamber. It was probably caused by driving the shield forward against a piece of rock bedded in the clay, several seams of limestone and shelly rock being found at the base of the clay. It was, however, not serious, and driving was continued, care being taken to clear out the excavation to the full diameter of the shield at the bent edge. By the middle of September 77 rings, being equivalent to a length of 192 lineal feet, had been erected, and at this date the buckling of the cutting edge of the shield was much increased, the edge being bent in one place 2 ft. inward from its correct position. This was no doubt caused by not clearing out the material carefully in front of the cutting edge. It was almost impossible to repair the shield where it was, and it was, therefore, considered better to continue on to the next shaft. As it was difficult to drive the shield properly with the bottom cutting edge so much bent, it was decided to drive a bottom timbered heading in front of the shield and to put in a concrete foundation the same mould as the shield, which the latter would run on. This heading was kept about 50 ft. in front of the shield, so as to give the concrete time to set. The excavation in the three upper floors of the shield was carried out without timbering. At this point there was about 2 ft. of sand in the bottom. The tunnel was then carried on in this way, as much as 5 ft. of completed tunnel being often constructed in the 24 hours. The depth of the sand in the bottom of the shield was gradually increasing as the tunnel was driven down grade, and a considerable amount of water was coming through it. The tunnel was now approaching No. 3 shaft, and it was seen that there was a connection between the water in the shaft and that in the tunnel, the water in the latter being reduced when "blows" of water and sand took place under the cutting edge of the caisson which was being sunk to form the shaft.

On December 16, 191 rings, equivalent to a length of 477 lineal feet, had been erected, and the sand was now up to the center of the shield. For a few days before this date the water in the bottom heading had been very troublesome, and on this day there was a large rush of water and sand into the heading, and in 24 hours it was full of sand. The back of the shield was at once timbered up, and the water rose in the tunnel to a height of 15 ft. at the back of the shield. The position was now as follows: The shield was being driven toward No. 3 caisson, and the cutting edge was only 67 ft. from the side of the caisson, and the face of the heading in front of the shield was only 37 ft. from the side of the caisson. The caisson itself was in process of sinking, and its cutting edge was still 4 ft. above the bottom of the tunnel heading. It was considered, therefore, that it would be dangerous to construct the tunnel any closer to the shaft until the latter was sunk to its full depth, as the sinking of the shaft might cause sand to be drawn from under the cast iron rings of the tunnel. Under these circumstances all work at the tunnel was suspended. The construction of a concrete bulkhead across the tunnel with air locks in it was commenced, so that the remainder of the tunnel might be continued under air pressure.

No. 3 caisson was sunk to its full depth on March 14, and on March 23 the tunnel was put under compressed air. After this there was, of course, no trouble with water. The old heading was immediately cleared of sand and the timbering was found very little injured. The heading was then continued into No. 3 shaft and the concrete foundation for the shield put in, and the latter reached the shaft early in May.

After compressed air was used no difficulty was found in carrying on the work quickly and satisfactorily, the only trouble experienced being in making a good joint between the tunnel lining and the shaft, as the ground here was much broken owing to sinking the caisson, and the compressed air blew out quickly, but it was accomplished after a week's work.

During the time compressed air was in use the greatest pressure necessary was 22 pounds to the square inch, and no attempt was made to use a higher pressure in front of the shield than in the tunnel.

The repairing of the shield in No. 3 shaft was then commenced. All the bent portions of the shell and inner skin were cut away and replaced by steel castings, and the shield further stiffened and strengthened in various ways.

Driving will now be started from the north side of No. 3 shaft across the river, and compressed air will be used all through this portion of the work. It is not expected that much difficulty will be met with at first, as there is a layer of clay between the top of the tunnel and the bed of the river for about two-thirds of the way across. After the clay dies out there is nothing but ballast, and for 350 ft. the depth of ballast between the top of the tunnel and bed of river does not exceed 10 ft., and at one point there is only a depth of 7 ft. It is proposed to tip a bed of clay into the river at this place, to prevent the air blowing out of the tunnel. The depth from high water level to the bottom of the tunnel here is 80 ft., which is equivalent to an air pressure of about 35 lb. per square inch. This is a comparatively high air pressure, and is about the maximum which men can work in continuously for any length of time; the average pressure will, however, be below this, as the range of tide is about 20 ft.

Much higher pressures have been used on some works in America; in one case a pressure of 48 lb. being used, and the men working only one shift of two hours out of the 24 hours.

The work done up to the present has, as may been inferred from the description, been rather of a tentative character, and much has been learned from it that will be useful in the portion of tunnel under the river. It was not expected that the first portion of the work would be otherwise, as it could not be hoped that a shield of such an unprecedented size and of such novel construction could be accurately managed without a little experience. The experience thus gained, and the precaution about to be taken of laying a bed of clay over the deepest portion of the river, will, it is hoped, enable the remainder of the work to be constructed quickly and safely, and furnish valuable and interesting data for future reference, and for a further more interesting description of this work.

The author, in conclusion, wishes to acknowledge the generosity of the London County Council, who last year obtained parliamentary power to enable them to compensate workmen injured while working under compressed air, and in cases of death to make allowances to widows and children, although the men are not working directly for the Council, but through the intervention of contractors.

STANDARD ELECTRIC LOCOMOTIVES.

The great industrial alliance of the Baldwin Locomotive Works and the Westinghouse Electric Manufacturing Company has gone to work with all the energy and resources at its command to produce a type of electric locomotive that will be an answer to the inquiries and demands that are being made all over the country. Plans are being drawn now at the Baldwin Works for the new trucks, under the supervision of David Leonard Barnes, the consulting engineer for the two companies, and in a few weeks, probably, the new trucks, and perhaps the completed locomotives, will be ready for the inspection of railroad managers.

Mr. Barnes designed the trucks and frame of the electric locomotive recently illustrated in the Scientific American, now in use in the Baltimore and Ohio tunnel at Baltimore, and the trucks under the electric motor cars of the Metropolitan Elevated Railway in Chicago were built from his designs. Mr. Barnes talked freely to a Ledger reporter of the developments of electric motive power and the electric locomotive, and outlined at considerable length the plans of the Baldwin-Westinghouse combination. He said:

"Up to this time the electric locomotives that have been built for heavy work have not been wholly satisfactory. They have been designed mainly by electricians who are not conversant with railroad practice in locomotive construction. A motor car, which is now commonly called an electric locomotive when it hauls several other cars, is in fact a passenger car, and when it is run at the head of a train it is as dangerous as it is to run a passenger train backward, unless special provision be made to construct the trucks as well mechanically as a locomotive.

"Suppose, for instance, a truck leaves the track; there is no locomotive ahead to hold the car body and to act as a protection to the car. Ordinarily trucks are only held to the cars by a king bolt, which, if it breaks, permits the car to slide over the truck, and in the case of an elevated road, to fall to the street. Defects of this sort are to be found in most of the motor cars that have been constructed heretofore.

"Realizing these dangers and the importance of a proper construction to prevent a setback in the introduction of electric locomotives for suburban work, the Westinghouse Company have entered the alliance with the Baldwin Locomotive Works in order to avail themselves of the wide experience of that firm in the construction of a proper electric vehicle to run at the head of a train. On the other hand, the Baldwin Locomotive Works has for some time realized that there will be a rapidly increasing percentage of locomotives in the future operated by electricity.

"Knowing that the electric motors that have been

put on electric locomotives so far have had some serious defects, that have caused great annoyance to those who have operated them in hard service, and, being equipped with special facilities for the rapid and cheap production of a suitable running gear for motor cars and locomotives, they have preferred to join themselves with the Westinghouse Company, so as to get the best possible electrical equipment, in order that their output of electric locomotives may give the same satisfaction to the purchaser that has been found with their steam locomotives.

"It is well known that the Baldwin Company have been in the front in all important improvements in steam locomotives, and have done more than any other concern to advance the use of the compound locomotive and the economical large locomotive boiler. It is their purpose in joining with the Westinghouse Company to gain the advantage of a superior electrical equipment, and especially the Tesla motor.

"The difficulties with the trucks for motor cars which have been built heretofore are that they are weak and inadequate for heavy work. The defects in the electric locomotives of the larger types not designed to carry passengers are in the complication, excessive cost, and probable great cost of repairs. The difficulties that have been found with the electrical parts of such locomotives are the failures of the commutators and controllers and the burning out of the armatures. The Tesla motor has no commutators. The Westinghouse Company have an important improvement in the electric air pumps for use with the Westinghouse brake. The electric air pumps used up to this time have been failures, owing to lack of capacity and to the great noise which they make.

"Notwithstanding these defects and some trouble incident to the collection of the current from the conductors, the economy of the electric system when compared with steam is so important that the defects just mentioned have not discouraged the use of electric power. To the contrary, the inquiries for estimates of the costs of new plants are very numerous and are rapidly increasing. For instance, on an elevated road —the Metropolitan, of Chicago, for example—the fuel used per ton mile costs only one-third as much as for the Manhattan elevated of New York City, on which steam is used.

"The most difficult problem now is to collect current from the conductors to operate the motors. There are three systems now in use, namely, the trolley, with which all are familiar; the third rail, which is an extra steel rail laid beside the track; and the automatic switch system controlled by the Westinghouse Company.

"The third rail seems to be impracticable for lines where there are grade crossings, and the trolley is still a problem unsolved for very heavy currents and high speeds The size of the conductors for heavy work with the direct current is so large that the trolley poles must necessarily be of great size and the overhead construction very heavy and expensive, especially on curves With the Tesla system, however, the overhead construction is lighter and the trolley more available for heavy work. With the Westinghouse automatic switch system there are no exposed conductors, the current being collected from contacts in the form of large buttons placed between the rails and which are only connected with the main electric cables when the motor car is passing. It is expected that this system of conductors and the Tesla motor will give to the two companies some superior advantages.

STANDARD MOTOR TRUCKS.

"The two companies will immediately bring out two standard motor trucks, one for light work and elevated roads, the other for the heaviest class of suburban traffic, suitable to haul 12 or 15 cars.

"By changing the power of the motors on these trucks they can be made to serve all the requirements of electric roads, from the lightest elevated with a maximum speed of 40 miles an hour to the fastest suburban work of 90 miles an hour. The trucks will be made of interchangeable parts, so that any damaged or broken portion can be readily replaced.

"The same trucks will do for switching and for freight work by putting them under a properly constructed car body and loading the car with pig iron or cast iron plates, so as to get the necessary adhesion. For special work electric locomotives will be built, having somewhat the appearance of the common steam locomotives. There will be special motors for mines and tramways, as there are now a considerable number of inquiries for electric locomotives for use on trunk lines where the power can be taken from waterfalls. Coal in some sections of this country costs $15 a ton on the tenders, and in such places there are often sources of power in running streams sufficient to make it worth while to equip with electricity.

A BETTER AND CHEAPER SYSTEM DEMANDED.

"There is a demand, and a lively one, from railroad companies for a system of hauling trains that will permit more trains to be run at a higher average speed for the same or less cost as with the present steam locomotive, and where there is any considerable traffic the electric system can be operated for less money, for there are less repairs, and only one motor man, at about $2 a day, instead of an engineer and fireman for $8 a day. Generally a cheaper fuel can be used, and a less amount in tons per car mile. Several of the larger roads have appointed one of their engineers to investigate and report on plans for operating their branch lines by electricity.

"The branch lines can frequently be made valuable feeders for the main lines by running frequent light trains in the place of the present heavy steam equipment which is now run at long intervals. It is universal experience that the more frequent trains and the better accommodations in light and cleanliness which are provided by the electric system materially increase the travel.

"In the matter of trunk lines, where there are many heavy trains, it has not yet been shown that the electric system is of any special advantage, as the freight and passenger traffic is now well handled with the steam locomotive, and would not be materially increased by using electricity.

HIGH SPEED TRAINS.

"The proposition to run high speed trains—that is, at 120 to 150 miles an hour—is one that has a possible practical value, but the question is largely an operating one. No railroad doing a common mixed business could permit such trains on a regular track, for the reason that the high speed would require that the fast trains be given the right of way under all circumstances, and this would necessitate the side tracking and the consequent delay of all other traffic. Such speed would require a special set of tracks, without grade crossings, and with a special signal system to show for not less than two miles ahead that the track is clear beyond question, for trains at those speeds cannot be stopped in less than one mile.

"No one as yet has seen a collision or derailment at 60 miles an hour, let alone 150, and as to the effect of the collision or derailment on the passengers, it may be taken as increasing as the square of the speed, that is four times as great for twice the speed. This emphasizes the practical difficulties in operating at such excessive speeds as have been proposed, and shows the needs of special tracks and a right of way entirely inclosed.

"There is at the present time no railroad company which would undertake to provide the facilities for a safe operation at over 100 miles an hour average speed and expect to pay expenses. It is perfectly possible to run a steam locomotive at an average speed of 100 miles an hour with a light train, but no railroad company is doing it, because the crookedness of the track, the grade crossings, and the interference of traffic will not permit it.

"What the public wants is not a high speed, for that is merely spectacular. They desire quick transit, and this is provided with a high average of speed as distinguished from a high maximum of speed."

TESLA'S MOTOR.

WHILE the Westinghouse Electric Company and the Baldwin Locomotive Works are combining the resources of their tremendous plants and are exerting all the energy that lies in millions upon millions of dollars to develop the possibilities of the Tesla motor, which some day will draw cars at a speed of 150 miles an hour, the inventor, Nikola Tesla, plods along in his workshop, planning and scheming and experimenting and maintaining a profound silence.

This workshop—a long, bare room at 46 East Houston Street—is fitted up with only a few electrical appliances. There Mr. Tesla is to be found every day, sitting at his desk, tinkering with figures and drawings. A Recorder reporter called upon him recently to learn something about this fabulous motor, which is going to send heavy trains rushing through space at such a terrific speed. As far as gaining any information from Mr. Tesla was concerned, the visit was fruitless.

Gently, yet very firmly—the manner was born of long experience—Mr. Tesla declined to be interviewed. The reporter, however, was allowed to see the marvelous motor, and later in the day, through the kindness of a gentleman who had devoted much time to studying the principle upon which it is constructed, was told exactly how the motor works. Truly, it is a marvelous invention The secret lies in turning the inert and seemingly lifeless force of magnetism into an active force more powerful than steam or a current from a dynamo.

If you take an ordinary magnet or a piece of iron, through which a magnetic current is passing, and hold it close to little pieces of iron or steel it will attract them and hold them motionless. This is practically all that the world has ever known of magnetic force. Now it seemed to Nikola Tesla—this was years ago, when he was a student in the Polytechnique—that this invisible force, pent up within the confines of the magnet, might, perhaps, be developed or transmitted or changed or utilized in such a manner that it would become active and quick where it had always lain passive. Upon this theory he worked for years, and its triumphant development led to the Tesla motor. The principle of the Tesla motor is this:

An electric current is passed through a circular magnet, in appearance resembling a life preserver. It consists simply of a ring of iron with copper wire bound around it. The electric current generates a strong magnetic current, which flashes around and around the circular magnet at terrific speed. Now if one holds a nail close to an ordinary electric magnet, it will be passive in the hand until it is brought close enough for the magnetic force to seize it, when it will fly out of the hand straight to the magnet. But—and here lies the wonder of it all—if one holds a nail close to this circular magnet of Tesla's, it will begin to revolve in the hand. That is, if the nail is held by the head and the point allowed to hang over the hollow center of the magnet, the point will move around in a circle, slowly at first, then faster and faster, until if it is dropped upon the table in the center of the hollow, it will spin around so rapidly that the eye cannot follow its motions.

One hears the explanation of the phenomenon—there are several magnetic currents in the iron ring, and they are chasing one another around in a furious race—and is as much mystified as ever. If one balances an iron wheel upon the nail or lets the wheel revolve upon a finger, using the finger as the axle, and holds it close to the magnet, it will fly around at a speed that will take one's breath away. It is not necessary to touch the magnet at all. All one needs do is to hold a piece of iron or steel in his hand and bring it within a foot of the magnet, and then he will feel a queer sensation as of some invisible force trying to draw the piece of metal out of his hand, and, failing in this, striving to twist it around in a circle.

If one places a wide board over the whole magnet, the force will make itself felt through the wood, for if a piece of iron shaped like an egg is dropped upon the board it will wobble around for a moment and then, as soon as it gains a little momentum, it will spin around on its narrower end like a top.

Such is the principle of the Tesla motor. In its application as a motive power on a railroad, the construction, of course, differs from that of the experimental magnet, but the idea is the same.

Here the circular magnet is attached to the bottom of the engine and the axle upon which the wheels revolve passes through the center of the magnet without touching it. When the current is turned on, the magnetic force whirling around in the hollow of the magnet catches the axle and turns it. The power for generating this magnetic current can be transmitted by underground wires for almost any distance, and there is practically no waste of power or energy.

The Westinghouse Company controls the American patents of this motor. Its application to railroads is merely one of its uses. Dozens of skilled mechanics are at work constructing machines which embody Mr. Tesla's idea in various forms and for various purposes, and electricians believe that before long it will have revolutionized electrical science.

As far as its ability to propel cars at a speed of 150 miles or more an hour is concerned, no expert whom the reporter saw has the slightest doubt of it. One electrician said:

"As far as speed is concerned, Mr. Tesla's invention contributes all that electricity can do as a motive power. There is not the faintest doubt in the world that the Tesla motor will propel a car at the rate of 150, 200—I hardly hesitate to say 300—miles an hour. Now, however, they must build engines and cars and roadbeds and tracks to stand the strain, and when they have done that rapid transit will be attained."—N. Y. Recorder.

SUGAR REFINING IN NEW YORK.

SYSTEMATIC refining of cane sugar did not begin with us until about fifty years before the revolution. Yet the business must have been prosecuted on rather a large scale for a small colonial town, for the principal military prison of the British during the war was a refinery which stood where the Mutual Life Building does now. Another refinery was on Wall Street, where the Assay Office is, and the Rhinelander Building towers up where an ancestor of the family after which it was named carried on his sugar works. These buildings were the largest in town when they were put up, with a few exceptions, and the structures erected for the use of this business during the lifetime of the present generation have also been very great ones. In 1860 there was no edifice in New York City higher than six stories, with the exception of some sugar refineries.

Sugar is produced only in the United States to any extent in Louisiana. Nearly all sugar refined in New York is imported, and arrives here ready to use, but dark in color and abounding in impurities. A rough process of refining is adopted in Cuba and the other sugar islands, but the result is something which no dweller in an American city would now put into his coffee cup, although until 1860 this was the common kind used. During the civil war, however, there was comparatively little discrepancy in price between white sugar and brown, and invention was much stimulated. Since that time brown sugar has been the exception and white sugar the rule. The object of the refiner is to take out the color and remove the impurities. This is accomplished almost entirely by filtration. Remove the dirt, and the sugar will clarify itself. This explains the reason why sugar refineries have so many stories; each floor makes one process in the course of purifying, as the dissolved sugar cannot be completely separated from the other matters contained in it at once. The purification must be progressive.

Sugar now enters into commerce in many ways once unknown, and the small establishments existing at the beginning of the century were for many years taxed to their utmost to keep up with the demand. The chief use of sugar or molasses one hundred years ago in any other than the domestic form was for making rum. Alcoholic beverages can be manufactured from anything that contains sugar, and rum in the early period of the American republic was much used. The molasses or treacle used for it was to some extent a by-product of New York refineries, but much the greater quantity thus required was imported direct. Coffee does not seem to have been much used by the common people one hundred years ago, but the taste for it rapidly spread during the next fifty years, and every cup must be sweetened. There is a jocular story that the saccharine substances used for this purpose in the West had two names—long sweetening and short sweetening. The latter was sugar, the former molasses. However this may be, both were demanded in the backwoods, and both were liked. Three other causes might be mentioned for the excessive use of sugar in the United States, as compared with other lands. Pies and cakes have always formed a very large proportion of the food of Americans; buckwheat or wheat cakes needed much molasses when molasses was popular, its place now being taken by sirup, and every housewife put up many preserves.

Candy manufacturing has always been a profitable calling in the United States, and conjointly with it has been the manufacture of ices and other confections which require much sugar. In no other country has ice cream such a hold as here. It was introduced into this city in 1795, by a Frenchman, but it had been known in Europe for at least forty years before. Goethe speaks of it in his autobiography, a lady of his acquaintance refusing to let her children eat it, ice being highly injurious. In this city fifty years ago two restaurants had a great reputation for ice cream. They were Taylor's and Thompson's, the price in each being fifteen cents a plate, which was more than the ordinary charge. Candy seems to have been first largely made at Ridley's, at 1 Hudson Street. There he began its manufacture in 1806. There are now many firms employed in this business in New York.

A new and very extensive use came up for sugar about the time of the Civil War by the introduction of canned goods. In a limited way it had been known for more than half a century that by putting properly cooked food into hermetically sealed cans the contents might be preserved for a score of years.

This was the plan adopted by Arctic voyagers. American women kept their fruits through the winter by boiling them in sugar, which is a well known preservative, but this process required a pound of sugar for a pound of fruit, and one out of every four or five jars spoiled either from climatic changes or from neglect of some of the little details. But the new method of canning required no sugar at all. Fruits would keep for years. What sugar was used in peaches, plums and other kinds was simply sufficient to heighten their palatableness. Still, the small amount thus required for each can or jar when multiplied by the

number of cans in the aggregate required an immense quantity of sugar. In 1855 none were commercially produced, but enough was known about the process in 1860 for nearly all housewives to attempt to do something in the new preserving way. Many firms invaded the fruit-growing region and began preparing food in quantities. Each year the output has become greater, until now it is estimated that many millions of pounds of sugar are necessary for canning operations. Sugar in summer, when this is going on, is higher than at any other time in the whole year.

For all these purposes, and for many more, New York refineries have supplied the material. They have been the chief makers on this side, and unite more capital and skill than those thus occupied anywhere else. Seventy years since the raw material arrived here in hogsheads and barrels as it does now. In it were fragments of cane, dirt, filaments of fungus and sand. Little organisms were also found in it, known as the sugar mite. All these things must be removed. The earliest plan was to dissolve the sugar and then let it crystallize again, but as then carried on the necessary heat to secure the evaporation injured the color. This evaporation was finally obtained at a low degree of heat by the use of the vacuum pan. Steam was introduced to give a more steady and equable warmth, and bone-black far surpassed bullock's blood in acting as a medium of purification. It has a power also of drawing out color from any liquid coloring matter held in solution, which it does by chemical affinity. The more thoroughly the liquid is attracted, the clearer is the product.

A list of fifty years ago gives the names of the sugar refiners at that time as Denis Harris, Harris & Ockershausen, A. & D. Havemeyer, Henry Meyer, Herman Rullhausen, R. L. & A. Stuart, Swift, Briggs & Company, Tylee & Mapes and Woolsey & Woolsey. Of them the Havemeyers and the Stuarts were the most distinguished. The latter were north country Irishmen, with great natural sagacity and power of attending to the details of business never surpassed in New York. Each left several millions of dollars. They were for many years peculiar among New Yorkers in refusing to remove their residences up town. The fine, handsome houses they dwelt in are still preserved near the City Hall Park, and it would seem that no one could desire to remove from such large and commodious dwellings. Their neighbors had gone away, however, although they also possessed fine houses. One of the brothers finally yielded to the encroachments of business, removing to the east side of Central Park, on Fifth Avenue, where his widow lately died. But the other refused to depart, though there was not another private house within a mile. He was comfortable enough where he was, and in the house he had occupied so long he died, the last New Yorker of means to live below Canal Street.

The Havemeyers, who were Germans, began business in New York about 1805, in a little building on Vandam Street. The original firm was the two brothers. Their first building was only a frame structure, 25 by 40 feet, and it was some time before they did sufficient business to employ seven men. A number of persons used to buy their supplies at the refinery in quantities of from one loaf to twenty loaves of sugar, and from one gallon to forty gallons of molasses, and the late head of the firm of Havemeyer & Elder himself drove around a wagon to supply his father's customers, some only needing what could be supplied in a jug. Raw sugar was then about 10 cents a pound and refined sugar 20 cents; in forty years the price sank to 8 cents for raw and 11 cents for refined. It is now about half these prices. In 1828 William F. Havemeyer, afterward the mayor, and his cousin, Frederick C. Havemeyer, who were sons of the original Havemeyers, entered into partnership in the same trade elsewhere, and continued until 1842, when both retired. F. C. Havemeyer began again in 1855, and in 1861 the firm was entitled Havemeyer & Elder. Since that time it has been the strongest and largest sugar refining house in the world. Another offshoot of the original refinery was the firm of William Moller & Sons, previously Havemeyer & Moller. In 1865 there were in New York the following sugar refineries:

New York Steam Sugar Refining Company; Williamson, Griffiths & Company; Johnson & Lazarus; John W. Brockhorn; Camp, Brunsen & Sherry; Harris & Dayton; F. A. MacCready & Company; Daniel Pomroy; Ockershausen Brothers; Plume & Lamont; Mollers, Hogg & Martens; Kattenhorn & Tuska; Greer, Turner & Company; Booth & Edgar; Breck, Cushman & Stanton; Mollers, O'Dell & Dosher; Brunjes Ockershausen & Company, and William Moller & Son. In Williamsburg there were Havemeyers & Elder, Sheppard Gandy, C. E. Bertrand & Company, and Wintjen, Dick & Schomacher; in Brooklyn, Meyer & Gomberat and Finken & Wheatly; at Greenpoint, Brown, Furbish & Company; and in Jersey City, Matthiessen & Wiechers. These factories were then producing goods worth $35,000,000 per annum.—New York Shipping List.

PREPARATION OF ELECTROTYPE MOULDS.

A BOOK by Julius Weiss, published by A. Hartleben, Vienna, treats the subject thoroughly. The following extracts are from a translation from this work in Paper and Press:

We have but little to say with reference to apparatus or baths, as copper solutions are most generally used for the latter, while the former are, inferentially, well known. The production of moulds and the preparation of originals to be copied demand the greatest care, and to these special attention will be paid. No portions of the original must be overlooked, as the success of a laborious manipulation depends, to a great extent, upon caution.

MAKING THE MOULDS.—The deposit of metal caused by the voltaic current is always formed at the negative electrode, which must hence be of a metal unaffected by the electrolytic metal solution. As sulphate of copper (blue vitriol) is frequently used in the bath, neither zinc, tin nor iron can be used; platinum and gold possess all of the desired qualities, but are too expensive. Copper is, therefore, ordinarily employed. The deposited metal covers the mould from all points, and an original object is thus rendered of no further value, or is damaged to a great extent. If the preservation of an original is necessary, one-half of the object will have to be completely insulated in order to remove the deposit. To obtain a duplicate without damage to the original, a mould must be produced. If a coin is the original, for instance, it is covered with melted wax or shellac, upon one side, the remaining side being well cleaned and placed in the apparatus. The coin is soon covered with a thin copper deposit. When this has become sufficiently strong, the coin is removed from the solution and the wax melted off over an alcohol lamp, after which the separation is easily effected. Copies in fac-simile of the original may be obtained from this matrix. While the most exact and durable, such matrices require so much time, care and outlay, that their use becomes permissible only in very fine works, or when a mould is to be frequently taken. Cheapness is the desideratum, and efforts have accordingly turned toward gypsum in which to mould a copy. If the matrix is to be used but once, it may be made from metal which will melt easily from the galvanic reproduction. Such an alloy is obtained from a composition of

Lead	3 parts.
Tin	2 "
Bismuth	5 "

This will melt at 58° C. The Boettger alloy, which melts at 69° C., is composed of eight parts of lead and three parts of tin. The subject to be reproduced is pressed into the molten mass of metal at the moment it hardens, or is arranged in such manner that the metal is poured upon the matrix itself, which has been provided with a border. If lead alloys are used for the production of matrices, we may recommend for the purpose the solder of the lead workers, the soft D'Arcet metal, and the alloy used for casting types. All of these alloys, after being freed from their oxides, are poured on a flat surface, and the object to be reproduced strongly pressed into them. Newton metal may also be used for this purpose, made up of

Lead	[illegible] parts.
Tin	3 "
Bismuth	[illegible] "

If special beauty of the model or matrix is not required, a clean, polished, leaden plate is sufficient. The object to be duplicated is placed upon this, and an impression is made by means of a strong blow, or with a press. Ordinary stereotype metal answers the same purpose when poured over a gypsum mould. For the production of these matrices, however, metals are not necessarily required, as every plastic and easily melted substance known can be employed, provided the surface has suitable conductivity. The best materials are sealing wax, wax, gelatin, a mixture of wax, stearin, and cleaning chalk, a mixture of wax and resin, or gypsum and gutta percha.

Sealing Wax.—When using sealing wax for smaller objects, a card is held over the flame of a candle and the heated part is rubbed with the stick of wax until sufficient has been applied. The original is then pressed in. If the latter is of wood, it must be first rubbed with olive oil in order to prepare it.

Beeswax.—If beeswax is used, the object must also be first rubbed with a little olive oil. The object, which has been first thoroughly cleaned, is then surrounded with a paper border, and the melted wax is poured in the receptacle thus formed over the object. Before the wax is poured off a fine brush must be passed over the surface of the original to insure the removal of air bubbles, dust, etc. The wax must be removed a day after its application. The paper border is taken away, and the matrix can be easily separated.

Coins and Medals.—To duplicate coins and medals, a mixture of wax and stearin is used, to which a little fine chalk or fine powdered white lead is added. The treatment is the same in all other respects as with the wax. This process is also utilized with a composition of yellow wax and resin in equal parts, care being taken, however, not to pour this composition over the object while it is too hot or fluid; it cannot be recommended because of its adhesiveness.

For more delicate objects, varieties of gelatin are used; but, according to Bouillet, the copper deposit becomes slightly brittle—a disadvantage only occurring when a large amount of gelatin has passed into the solution. A smaller quantity of gelatin causes a rose-colored deposit; matrices made of gelatin are not durable. A good glue solution consists of twenty parts of glue and two parts of brown sugar, dissolved in as much hot water as will not prevent the entire mass from solidifying when cold. The composition is poured hot on to the matrix and is allowed to cool, when the form may be lifted off. With this elastic form a solid form may be subsequently prepared by adding to the former twenty-six parts of yellow wax, twelve parts of calves' tallow, and four parts of resin, which are poured in afterward. This composition is much better without the brown sugar.

If the objects to be duplicated will not withstand heat or pressure, matrices are made of gypsum. This substance is prepared by running the burned gypsum through a sieve, and by mixing one part of gypsum with two and one-half parts of water. To very fine forms a little burned lime is added, while duplicates of extremely fine originals, medals, coins, etc., are best produced from burned alabaster—which is also a gypsum. Instead of mixing the powdered gypsum with rain water, or boiled and then cooled spring water, sour milk may also be used for this purpose, after which the gypsum will become very hard. Gypsum can be made still harder by adding gum arabic, borax, or alum; in the last two instances the burned gypsum is dampened with a solution of the salt, burned a second time and pulverized. When used with alum, it is mixed with corresponding solution; when borax is used, water is applied. To prevent the gypsum from hardening too rapidly, a little glue is added to the water, which will harden the mass and give it the appearance of marble, and a decided transparency. When this composition is prepared, the original is cleaned and rubbed with a well-drying linseed oil, nut oil, or white varnish, or, to prevent adhesion still more effectually, the originals (if they are small) are placed in a solution of chloride of zinc 25° to 30° a few seconds before the duplication takes place. With larger objects, covering with the chloride of zinc solution is sufficient. Engraved surfaces are first treated with a preparation of saponified water and oil, and then with a solution of chloride of zinc, 40° to 50°; this is applied with a brush.

If the matrix is to be made of gypsum, the object is surrounded by a three or four fold border of paper, only a thin, watery solution of the gypsum being first applied (so as to avoid air bubbles); the remaining gypsum is then added. To prevent air bubbles in the gypsum while stirring requires care; and the correct amount of water must be present, so that the composition will be neither too thick nor too thin. To still further decrease the liability of air globules in the gypsum, it is advisable to freshly burn the latter, or at least to heat it over the fire until all dampness has been removed. After the gypsum has stiffened—which will occupy three or four hours—the paper border is carefully removed and the original loosened from the matrix. This latter, heated to 48° R., is dipped into melted wax or stearin, which is allowed to penetrate the mass; or the hot matrix is placed with its back upon the melted mass until it has penetrated through the gypsum to the face. Instead of wax, melted wax and colophony may be used, or a solution of colophony in oil of turpentine. All this is employed to fill the finest pores of gypsum and obtain a very smooth surface.

An extremely durable matrix is made with gutta percha. Knead a good, clean gutta percha (which must become highly plastic when heated, and must not be too adhesive or harden too quickly) that has been placed in hot water carefully and with wet hands. Karmash recommends heating over a dry source by placing the gutta percha on a coarse wire sieve, which is held over burning coals and turned from time to time until the mass becomes tacky, after which it is rubbed with graphite. The mass having become cold in a uniform and moderate way, the original, which has been provided with a protruding edge of metal and dusted with graphite, is covered therewith, and the whole sharply pressed together in a screw press. The correct degree of pressure is best acquired from experience. After perhaps half an hour has elapsed, the matrix will have hardened and be ready to take out.

Kress Composition.—Another excellent moulding composition for matrices of this kind has been discovered by Kress, who uses twelve parts, by weight, of white wax, four parts, by weight, of asphaltum, four parts, by weight, of stearin, and two parts, by weight, of tallow. The asphaltum is first melted; to this the wax is added, then the stearin, and finally the tallow. After the entire mass has liquefied and been well stirred, enough lampblack is added to impart a fine black color. To preclude the adhesion of the original, and to render the mass more homogeneous, a little fine gypsum is added, stirred well into the mass, and thoroughly worked in. With this composition, in which too much gypsum will render it excessively heavy, forms may be produced from gypsum originals by placing the latter in lukewarm water until it has saturated the mass—which may be noted from the cessation of air bubbles arising. The gypsum original must be free of water on the surface, after which the composition, which must not be too hot, is poured over it. When the mass has cooled, the form can be easily lifted. If the gypsum original has been treated with glue water or dissolved gum arabic, care must be taken that none remains upon the surface, and, before pouring on the mixture, that the surface be rubbed with oil.

The foregoing composition, offered by Kress, has the following advantages: (1) After the deposit of copper has been formed, it can always be remelted and used again, and if it becomes brittle through frequent remelting, it can be renewed by adding a little yellow wax or tallow. (2) It can be very easily handled, and yields a mould of the finest detailed character. Even the lightly etched tones of an aquatint are thus reproduced, and landscapes with etched cloud effects are exactly copied. (3) Large objects with finely engraved lines, which can only be moulded with great difficulty in gutta percha on account of the pressure and extent of the gutta percha needed, may be moulded with the utmost ease. (4) Small objects such as coins, medals, relief landscapes, etc., can be made by the dozens simultaneously. The moulder places the originals upon the table, surrounds them with a strip of potter's clay, and pours the melted, though not too hot, composition over one object after another. Such matrices may be lifted without difficulty after this "casting," and after they have been made conducting by means of dry powdered graphite, applied with a not too soft brush, are ready for the deposit.

MAKING THE MOULDS CONDUCTING.

All of these non-metallic moulds are non-conducting in the state described, and must be metalized before deposition begins. This is accomplished by means of heated graphite or by metallic salts. The superfluous edge of the mould having been cut off, the latter is covered with graphite (plumbago) in the finest of powder; a fine brush is used, and the graphite may either be dry or may have water and spirits of wine added. A very thin conducting layer is thus formed, which, when dry, is rubbed with a soft brush or long-haired velvet until all extraneous graphite has been removed and the surface has a metallic gloss. The Spanish, Siberian and famous Borrowdale (in Cumberland) graphites are particularly adapted for this purpose. The graphite last named is remarkably clean, cheap, and may be converted into a very fine powder, which is a good conductor of electricity. In using lower grades of graphite they are placed in a crucible which is closed with a lid, fastened with clay earth and exposed to the highest possible heat (glowing). After sufficient heating the graphite is rubbed to the finest powder and kept in this state. It is much better, however, to use only the best grades of graphite, as the powder, which has been dusted on dry, does not always adhere to the mould. Ibbotson dipped the object in a solution of phosphorus mixed in oil and termed his invention "electrotype." In this method the original is covered with a thin film of phosphorus upon which the deposition takes place in a fine and uniform manner. The process can only be used for gutta percha and gypsum matrices.

A still further means of metalizing the moulds consists in applying dissolved metallic salts, usually silver nitrate (lunar caustic), ducted unto the surface, etc. Prepare by heating a solution of phosphorus in ethe-

real alcohol; the mould to be rendered conducting is first dipped in a light solution of nitrate in aqueous spirits of wine, and then immediately after is subjected to the vapor of the phosphorus solution, from which a few drops have been placed upon a hot sand bath provided with a support for the mould. After a short time the mould is covered with a thin silvery film. The principal feature of this process is the complete dampening of the mould with the silver nitrate; hence as much of the solution as can be placed upon the surface is applied and allowed to evaporate in the open air, the process being repeated as often as may be required to obtain a fine, black, homogeneous surface, with which the surface of the mould is covered, and from which the metal is reduced either by the effect of light or by means of steam. The surface of the mould can also be washed off with ammonia and the mould itself immersed in the nitrate of silver, proceeding as described; or chloride of silver or nitrate of silver may be dissolved in ammonia, and this solution can be used in place of the lunar caustic solution. Non-metallic and delicate subjects or those with fine reliefs or engravings are rendered conducting for galvano-plasty by means of a silver salts solution, which is reduced by exposure to sunlight or the influence of hydrogen or phosphorus vapors; the latter are very dangerous as to fire, and are especially poisonous. C. Cazeneuve, therefore, reduced his silver nitrate with mercury vapors. He dissolved the nitrate of silver in wood alcohol, which evaporates better and dissolves the silver oxide with more facility; it also impregnates the non-metallic mould better, while being at the same time cheaper. After treating in a 10 per cent. solution of lunar caustic, to which he added 3 per cent. of nitric acid to prevent the reduction of the nitrate in the wood alcohol, he allowed the drops to run off the surface, placing it while still damp over a saturated solution of ammonia through which a double salt of silver and ammonia is formed in a few seconds, which can be very easily reduced.

SIZING PAPERS WITH WASTE SULPHITE CELLULOSE LIQUORS.

THE problem to utilize in some way the waste liquors from the sulphite wood pulp manufacture has occupied chemists for some years. Primarily these attempts have been prompted by a desire to obtain some useful and profitable products, but the indefinite character of the composition of the organic bodies contained in the liquors, and their very complex character, have made a solution of the problem more than ordinarily difficult. So far neither bodies of a simple nor profitable nature have been isolated from these liquors, but, owing to their plastic character when in the concentrated form, the idea of a dextrine or gum substitute has been uppermost in the minds of investigators.

Apart from the attempts to obtain useful products, the necessity has arisen in many localities to deal on an extensive scale with these liquors instead of running them off into the nearest watercourse, to avoid pollution. The magnitude of such a treatment, in a sulphite factory of average size, is very great, the liquors being dilute, acid in character, and possessing a somewhat disagreeable smell.

Prof. A. Mitscherlich has been one of the first to deal with this question, and he has taken out in his native country and in England many patents embodying processes for the preparation of useful products from these waste lyes. Recently he has established a works in Germany for the manufacture of a "size" for paper makers which is prepared from an animal gelatine or glue in combination with the tannin and closely allied bodies in the waste sulphite liquors, the size being sold in a concentrated condition. It is claimed that this size imparts to the paper similar properties to animal size, and can be applied in the same way as ordinary resin soap, namely, by precipitation with alum. The size itself is a yellow fluid, of a neutral reaction, and can be diluted in any proportion with water. The percentage of sizing ingredient corresponds to its specific gravity. For every increase in sp. gr. of 0·004 the percentage of size increases 1·0 per cent. The actual contents of size in any solution can be estimated by precipitation with alum, filtering off the precipitate through a weighed filter, after shaking violently, and finally drying in the air and weighing.

When a diluted solution of this size is treated with a solution of alum or sulphate of alumina, a white flocculent precipitate of a cheese-like character is thrown down, which is soluble in alkaline solutions, and especially in solutions of soda. When, therefore, the size is precipitated in the beating engine with alum, as in resin sizing, the precipitate coats the film, binding them together, and, owing to its adhesive nature, attracts and holds fast the loading materials, such as china clay and other mineral matters, and mechanical wood pulp. Although the "size" is dark colored, it has no influence upon the paper pulp, provided the alum is free from iron.

Printing papers can be sized to any desired extent with this size, and they claim to effectually resist printing inks passing through their texture. It has been found, however, that the best results for writing papers are obtained when the size is mixed in the engine with resin size, varying in the proportion from 4:1 to 1:1; the quantity of each depending upon the kind of the paper stock and the degree of sizing required. An addition of 3 per cent. of the size is suitable for ordinary printing papers, while for those containing much loading materials 1½ per cent. resin size should also be added. Any appearance of "froth" in the stuff is killed by the time honored remedy—a small addition of petroleum or seal oil.

It is obvious that the size thus precipitated upon the paper films is insoluble in water. The presence of the gelatine, which is in combination with the "tannin bodies" derived from the waste sulphite liquor, cannot therefore be ascertained in the ordinary way by simply macerating the paper in hot water and taking the clear solution. But if the dissolving water be made slightly alkaline, the size passes readily into solution, and the usual tests can be applied to prove the presence of gelatine, etc.

This new size is cheap, and in the concentrated state remains unchanged in closed vessels. It can be kept for any reasonable time in a warm or cool place. It is always ready for use, requiring no previous preparation, and imparts to the paper stock all the characteristics of animal sizing. Its strongly adhesive property conduces to the economy of "loadings," and it is said paper can be made entirely from mechanical wood pulp by its use. Papers sized with it bulk well, and their color is less subject to change when exposed to sunlight.

APPARATUS FOR VERIFYING THE LAW OF THE EQUILIBRIUM OF THE WEDGE.

THE following is a very simple apparatus that I have devised and had constructed for verifying the law of the equilibrium of the wedge. Friction exerts no perceptible influence upon it. A piece of plate brass cut into the form of a wedge, two of the sides of which are beveled (Fig. 1), slides by its own weight between two pulleys fixed near the upper ends of two strips of tempered steel. The two pulleys, which are primarily tangent, are thrust apart, through the effect of the wedge, to a certain distance indicated on each side by indexes upon the divided arc that is seen behind the wedge. The weight of the latter (500 grammes) is the power, and of the two pressures exerted at right angles upon the sides by the pulleys, one is the resistance and the other the reaction. Now, the wedge is so shaped that the length of its side is double the length of its head, and therefore the pressure upon each of the sides should be one kilogramme in order that there may be an equilibrium.

This is verified in the manner shown in Fig. 2. The wedge is removed, as is also one of the pulleys. The apparatus being then caused to tilt toward the side of the removed pulley until a projection in the joint abuts against the support, we suspend the one kilogramme weight that accompanies the apparatus. The lower strip cedes in bending under such weight, its extremity remaining horizontal. It is then found that

FIG. 1.

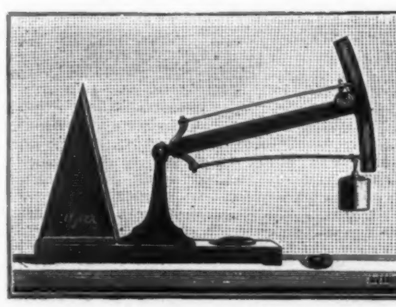


FIG. 2.

APPARATUS FOR VERIFYING THE LAW OF THE EQUILIBRIUM OF THE WEDGE.

the index points to exactly the same division as when the wedge was acting. It is well to weigh the wedge and weight before the pupils, by means of a balance, before or after the experiment. As the apparatus has but a single wedge and a single weight, there are really no divisions required upon the arc. It would suffice to mark the extreme positions of the flexible strips by two lines to the right and two to the left. A demonstration by a single wedge of fixed angle is sufficient and has the advantage of requiring very little time. Nothing would be simpler, however, than to construct a wedge with angle variable by means of a hinge. The constant weight would then be replaced by a scale pan, the weight of which would have to be engraved upon it in order to be added to that of the weights it was to receive.—T. Escriche, in La Nature.

HYDROGEN PEROXIDE.

NATURE asserts that hydrogen peroxide has at last been isolated by Dr. Wolffenstein in the laboratory of the Technischen Hochschule at Berlin, and the somewhat surprising fact demonstrated that this substance, which has hitherto been regarded as possessing but little stability, is capable of actual distillation with scarcely any loss under reduced pressure.

In attempting to concentrate solutions of hydrogen peroxide in vacuo by the method of Talbot and Moody, and also in the open air upon the water bath, a solution as strong as 66 per cent. H_2O_2 was obtained, but with a loss of over 70 per cent. of the original amount of peroxide employed. Moreover, it was found that when the common commercial 3 per cent. solution is concentrated, the percentage of H_2O_2 may be brought up to 45 without the loss of any considerable quantity of the peroxide by volatilization, but that as the concentration continues to rise above this limit, the volatilization of the peroxide increases at a very rapid rate. For the great loss was proved not to be due to decomposition, but to actual vaporization of the substance.

Evidently hydrogen peroxide is remarkably stable at the temperature of a water bath. An attempt was therefore made to actually distill it under reduced pressure. A quantity of commercial peroxide which had been further concentrated until it contained about 50 per cent. of H_2O_2 was first purified from all traces of suspended impurities, and at the same time still further concentrated by extraction with ether. After evaporation of the ether the solution was found to contain 73 per cent. H_2O_2.

This solution was then submitted to distillation at the temperature of the water bath and under the reduced pressure of 68 mm. of mercury. The distillate was received in two fractions, boiling at 71°—81° and 81°—85° respectively. The first fraction contained 44 per cent. H_2O_2, while the latter was found to contain no less than 90·5 per cent. Upon again fractionally distilling the latter product a large proportion distilled at 84°—85°, and this fraction proved to be practically pure H_2O_2 containing over 99 per cent. of the peroxide.

The liquid thus isolated is a colorless sirup which exhibits but little inclination to wet the surface of the containing vessel. When exposed to the air it evaporates. It produces a prickly sensation when placed upon the skin, and causes the appearance of white spots which take several hours to disappear again.

As regards the much discussed and disputed question of the reaction of hydrogen peroxide toward litmus, Dr. Wolffenstein finds that even when the pure liquid is made strongly alkaline with soda and again distilled, the distillate exhibits strong acid characters, so that the acid nature of hydrogen peroxide must be regarded as fully established.

It is finally shown that the use of ether in assisting the concentration is by no means essential. Ordinary commercial 3 per cent. peroxide can be immediately subjected to fractional distillation under reduced pressure and a fraction eventually isolated consisting of the pure substance boiling at 84°—85° under a pressure of 68 mm.

THE LIQUEFACTION OF GASES.

PROFESSOR DEWAR, in some recent lectures at the Royal Institution on "The Liquefaction of Gases," said: Although it is well known that the liquefaction of gases was first worked out at the Royal Institution by Faraday, perhaps few were aware that twenty-two years previously Dalton had pointed out that there could scarcely be a doubt as to the reducibility of gases to a liquid state by sufficiently low temperatures. He here drew attention to a series of barometrical tubes, which he said that he believed had been in the Royal Institution ever since Dalton lectured there, and with which Dalton exhibited the different vapor pressures over mercury ether, bisulphide of carbon, alcohol and water by means of the extent, when these liquids were placed in the upper part of the tubes, to which they depressed the mercury. Dalton, therefore, concluded that liquefaction of the gases must occur by sufficiently lowering the temperature and increasing the pressure.

This led to discussions in the scientific world as to the relative advantages of pressure and temperature for the purpose; Davy thought pressure to be of the greater importance. About this time discussions also took place on the influence of pressure on chemical stability, and especially was this the case at Edinburgh in relation to geology, when the antagonists of the plutonists asked the latter to account for the vast deposits of carbonate of lime in the earth and its organic structure, instead of the presence of lime itself, if the whole had once been in a state of intense heat. Mr. Hall heated chalk into lime under great pressure, and when the apparatus cooled, the contents went back into the condition of chalk again.

Davy being away on a holiday, Faraday made some solid hydrate of chlorine, the crystals of which formed at the temperature of ice will keep in a sealed tube. Faraday was engaged in heating this tube one evening when Davy's biographer called in and noticed that the glass tube contained oily matter, bringing forth some remarks to Faraday about the use of dirty tubes, which the latter deemed to be just. He accordingly filed off the end of the tube, and all its contents vanished. Davy was told of this the same evening by his biographer, and said that he would look into the matter on the morrow, when Faraday told him that it was liquid chlorine. There was at that time much ill feeling between Faraday and Davy, but that was ephemeral. Faraday had to puzzle the matter out himself, and thus he made liquid chlorine. Davy liquefied hydrochloric acid gas, and after that left the investigation of the liquefaction of gases to Faraday. Davy thought that such liquids would be more efficient than high pressure steam as a motive power, that they would be good for saturating liquids with gases and that they would be efficient cooling agents, in the first of which anticipations he was wrong.

Professor Dewar here exhibited some yellow crystals of hydrate of chlorine in a closed tube. When he heated this tube in hot water the crystals liquefied, and chlorine gas was given off in bubbles. Then liquid chlorine formed near the surface of the water, hanging down from the surface like a large elongated drop, which in time sank to the bottom of the tube by its own weight. This was the "greasy" looking matter noticed by Faraday. On cooling the tube and vigorously shaking it, the yellow crystals of chlorine hydrate came back again. Faraday then applied a manometer to ascertain pressures in this class of experiments; it was one in which mercury compressed air. These manometers often burst, and screens and masks were freely used to protect the workers. In this way many gases were liquefied at measured pressures. Faraday stated that he found out afterward that he was not the first to liquefy chlorine; that a Mr. Northmore had done it before, but Faraday did not know it at the time.

Cagniard de la Tour worked much at this subject, including that class of experiments in which a liquid, say water, is heated to the boiling point, a cork then put in the mouth of the flask, which after its removal from the flame can then be made to boil again by pour-

ing cold water over the upper part of the flask, thereby reducing vapor pressure. Tour thought, "If I make the vessel strong enough, will not the liquid always remain there when heated? Is there not a limit to the elasticity of the liquid?" He filled a tube half full of ether. The liquid under sufficient heat increased in volume until it filled the whole tube, and everything was gas in twice the liquid volume. Some of the tubes did not burst. He measured the pressure, and proved that the liquid condition disappeared at one particular temperature, independently of the pressure. At that temperature it cannot be liquefied with any degree of pressure. Tour showed that Davy was in error in supposing pressure to be all important.

Thilorier, of Paris, made some apparatus on Faraday's principle, but on a gigantic scale, in which he liquefied carbonic acid in bulk, and he proved that when that liquid was projected into air, a solid was produced by the cold of its own evaporation. This solid carbonic acid has the curious characteristic of possessing a boiling point lower than that of the liquid acid. Unfortunately, Thilorier's apparatus was made of cast iron—it burst, and killed two assistants.

Professor Dewar then took a strong metal tube, about six inches long, closed at each end with plugs of quartz, and placing it end on to the condenser of the electric lamp, so that what took place inside the tube could be seen by suitable projection upon the screen, he slowly discharged into the tube carbonic acid under heavy pressure. It could be seen liquefied, half filling the horizontal tube, with patches of carbonic acid snow floating on the liquid, and some atmospheric disturbance above.

Lastly, he exhibited the well known, but not often seen, experiment of freezing mercury in a red-hot crucible, by dropping a compressed and externally cruci-shaped lump of carbonic acid snow, moistened with ether, into a red-hot platinum crucible, and putting a few drops of mercury into a hole in its center. The mercury then froze to the end of a wire, with which it was withdrawn and exhibited. This experiment merely means, he said, that the boiling point of carbonic acid is constant at 80° below the zero of the Centigrade scale. The range of temperature about which we know anything, he said, extends over 3,000° of the Centigrade scale; the temperaure of the sun is a disputed point. He was doubtful as to a portion of the excessively low temperatures said to have been encountered by man in the Arctic regions; according to Dr. Janssen —42° Centigrade was the lowest temperature at the top of Mont Blanc last winter.

He told how carbonic acid had the peculiar property of possessing a boiling point lower than its melting point; in fact, it is a boiling solid. In illustration of this, he pressed some solid carbonic acid into a kind of snowball, tied a piece of string round it, and suspended it in water in a glass trough with parallel sides, so that he could project an image of the block upon the screen. It was then seen to be giving off carbonic acid gas freely. In moulding it with the fingers, he said, it feels no colder than snow, because in reality it never comes into contact with the skin. There is a layer between in the spheroidal condition. This is why, to bring it into immediate contact with bodies, it is usual to wet it with ether. Thilorier's apparatus was lent to Faraday by Mr. Graham, and by old books on the premises he found that Faraday first used it in the Royal Institution on May 18, 1838, three years after Thilorier's discoveries. After that only in 1845 did Faraday return definitely to this class of researches, and by means of solid carbonic acid turned his attention to the production of lower temperatures. Others were also at work. Leslie and Wollaston produced low temperatures by the application of a vacuum to promote evaporation, and for the purpose of distilling; Faraday forced carbonic acid to boil in a vacuum, and thus reached a temperature of —110° C., at which temperature he then compressed his gases. He succeeded in liquefying marsh gas, and most of the compound gases, and came to the conclusion that liquid nitrous oxide would give a lower degree of cold, but failed in his experiments thereon, not, however, because his principles were wrong. This was in 1845.

The next step was the liquefying of nitrous oxide by Natterer, of Vienna, who found that nitrous oxide worked best when mixed with bisulphide of carbon, just as Thilorier discovered that solid carbonic acid worked best when mixed with ether, so as to be brought into contact with bodies. Nitrous oxide has the advantage, for the purpose of obtaining lower temperatures, of being a liquid, but is easily transformed into a solid; nitrous oxide ice is ten degrees lower than carbonic acid ice. At this point investigation into the production of lower temperatures came to an end for a time, and other branches of the subject were taken up. Nitrous oxide boils steadily at about —90° C.; its boiling point and its melting point are exceedingly near together; it supports the combustion of glowing charcoal for a time, and then the cold puts it out; it instantly solidifies a drop of mercury, which sinks to the bottom of the test tube, and sticks there as if soldered thereto. Then followed the examination of constants, chiefly by Regnault, who dealt chiefly with the permanent gases to get at fundamental laws. In 1862 and 1863 came the exceedingly fine and exact work of Andrews, of Belfast, on the liquefaction of gases in capillary tubes. Andrews' compressing apparatus was then improved into Cailletet's pump. Some good work was also done by Dutch philosophers.

While this was going on, Pictet and Cailletet were working independently at first, and the former working at pressures of 300 and 400 atmospheres at a temperature of —110° C. obtained a mist of liquid oxygen. Cailletet did a very ingenious thing by deliberate intention; he introduced a quick means of expanding compressed gases, to produce increased cold, by the introduction of a valve into his apparatus, which valve could be suddenly opened; in this way he obtained mists in closed tubes of all gases, including hydrogen. Both investigators came to the same conclusion, namely, that the permanent gases were capable of liquefaction. The matter rested there for some time, and Cailletet added largely to our resources in the way of improved compressing and indicating apparatus, also in improving the manometer by absolute corrections. With an improved compressing pump he liquefied ethylene, which formed a clear transparent liquid of a temperature of — 100° C., which is easy to remember, as it is the same temperature below zero that boiling water is above zero. Ethylene was used by Cailletet in his experiments on the liquefaction of oxygen. Professor Dewar showed how liquid ethylene would roll about in the spheroidal state on the surface of cold water, and would burn when ignited by a flame. When the ethylene was used not boiling in air, but under special evaporation, a bitter controversy arose; it was said that others were taking the investigation out of Cailletet's hands, and that if he had been let alone, he would have done the same thing.

Professor Dewar, in his third lecture on this subject, delivered on Thursday, May 9, said that at this stage a distinguished student, Wroblewski, took up the subject. He was born at Grodno, in Poland, in 1845, and took part in what was known as "the rising of Poland," the result of which was that in 1863 he was sent out of the country, and lost to sight for four years, in Siberia, where he eked out a miserable existence. Then, because of the strong influence of his friends, he was allowed to return to Russia, and to live in an obscure town; at last he was set free, and at once left for Germany. He consulted Kirchoff and Clausius at the universities of Heidelberg and Bonn about a new cosmical theory he had thought out in exile, and received scanty encouragement; then he saw Helmholtz at Berlin, who recommended him to begin physical work bearing upon his theory, after which he worked for two years under Helmholtz. His papers on gaseous problems attracted the attention of Clerk Maxwell. Subsequently he went to the Ecole Normale at Paris, and worked with Cailletet in his experiments with gases; there he saw the liquefaction of ethylene, also what might be called the production of a kind of "champagne froth" of liquid oxygen. Wroblewski returned to Cracow, and took with him the compressing pump and other apparatus; he soon got ahead of Cailletet, and subsequently he was associated with Charles Olszewski. Wroblewski and Cailletet had a quarrel; the latter accused the former of picking his brains, and Wroblewski replied that science knows no monopoly of ideas; the Paris Academy crowned Cailletet as the liquefier of oxygen, while the Germans voted honors to Wroblewski.

In the work then and since being done, there was nothing new in principle, only improvements in technical details. Professor Dewar here pointed out what he called "three little improvements" which he had made in Cailletet's apparatus, the principal of which was the use of the system of vacuum jacketing to prevent the access of heat. He also reduced radiation by coating the vessel containing the cold liquid with silver or with frozen mercury, so that the liquid would last hours longer than it did before. He poured some liquid oxygen into an unprotected test tube, which began steadily to give off outside what looked like smoke. It was the outside air condensed by the cold. With a proper vessel nothing of this sort occurs, and the outside keeps bright for a long time. He then froze alcohol with liquid oxygen, as on a former occasion, and turned out a small lump of it as hard as a stone. He showed how India rubber tubing went hard at the temperature of liquid oxygen, and could be broken like a piece of stick, and reduced to powder. A child's little India rubber balloon shrank to a third of its former size in liquid oxygen, showing, therefore, that the air inside it possessed three times its former density. Solid carbonic acid, which is a boiling solid in air of the normal temperature, neither boiled in liquid oxygen nor gave off bubbles therein, but made the liquid milky in appearance, which milkiness was removed by filtration through filtering paper.

Professor Dewar then performed an experiment which, he said, had never been publicly exhibited before, namely, showing the effect of low temperature upon gaseous bromine. He took a large bulb filled with brown gaseous bromine. The bulb had a cup-shaped indentation on its upper part, into which the lecturer poured a little liquid oxygen. Inside the bulb the vapor began to condense on this cup, until it was all deposited as a bright red solid, not in the least brown in color. By freezing a thin spiral wire of tin, it became hard enough to lift a weight without being pulled straight, and the mercury in a Torricellian vacuum, exerting a pressure of but a millionth of an atmosphere, was condensed and rendered visible by cold applied outside the bulb. A phosphorescent vacuum tube ceased to phosphoresce or to pass electricity under the influence of intense cold, showing that "something" had been frozen therein. He repeated some of his former experiments on the magnetic properties of oxygen, and said that Janssen discovered the remarkable absorption bands of that gas. He showed how intense cold would alter the colors of certain substances, changing, for instance, the redness of iodide of mercury to light yellow.

Although all chemical action seems to cease at these low temperatures, it can be made to go on sometimes by energy supplied from outside, so that a kind of "fight" takes place. In illustration of this he said that he would burn a diamond in liquid oxygen, an experiment never shown before. He dropped one or two red-hot diamonds into liquid oxygen; the cold put them out, and they sank to the bottom. Then he made a diamond extra hot by means of a blowpipe flame; it caught fire, and burnt steadily on the surface of the liquid oxygen, which became opaque because of the carbonic acid given off. He also burnt some graphite on liquid oxygen, and said that the combustion of this form of carbon is sometimes more difficult to start than that of the diamond. Other forms of carbon are burnt more easily. The combustion of carbon with liquid oxygen unexpectedly results in the production of ozone, for the liquid afterward smells strongly of that substance.

Professor Dewar, in this lecture, drew attention to two lists relating to the recent history of the researches on the liquefaction of gases.

Among the experiments was one in which carbonic acid gas was allowed to enter a tube with liquid oxygen at the bottom. A kind of miniature snowstorm was the result, as flakes of solid carbonic acid fell. An entirely new experiment was the combustion of hydrogen below the surface of liquid oxygen, by the insertion of a minute jet of burning hydrogen below the liquid. The water formed rises from the liquid and goes off as what the lecturer called "fume," no ice being deposited anywhere. At the same time a quantity of ozone was formed. In another experiment he filled a 4 in. diameter globular bottle of thin glass with filtered liquid oxygen, which was of a delicate blue color. This he used as a lens in front of the electric lantern, and with the rays passed through it he set fire to brown paper to a smouldering extent. He showed that under the cold of liquid oxygen common red sealing wax changes to an orange color. Lastly, he directly liquefied the air of the theater by causing it to condense outside an abnormally cold test tube, and to fall in drops.

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TABLE OF CONTENTS.